Horticulture Research Strategy

2016-2030

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Foreword

In the years ahead agriculture awaits a daunting task of feeding burgeoning population in a resource constraint world and under the influence of climate change while keeping society and environment safe. Agricultural research undoubtedly plays a key role for agriculture to fulfill its objectives. This, however, cannot be addressed through impromptu or with only a short-term research plan. Therefore, while addressing instant problems agricultural research needs to anticipate future needs as today's research will guide tomorrow's solutions and approaches in farming and agri-business. This is especially important in view of lag between conceiving and maturity of research, uptake by users, and ultimate translation into development.

This national program/thematic area-based strategy was therefore drawn within the context and in conformity with the need and evolving national and global emerging trends while taking advantage of the current and emerging opportunities. The strategy is framed in alignment to, among others, Global Sustainable Development Goals (SDGs), the various Ethiopian Ministries Growth and Transformation Plans(GTPIIs), EIAR's GTPII, National Agricultural Research roadmap, Climate Resilient Green Economy strategies and of course under the rubric of the country's medium term vision to become a middle income country by 2025.

While the strategy is lopsided on primary sector (production end) research attempt was also made to establish relevant links to the value networks/chains/ research to the extent it can be stretched.

The strategy development was initiated by and is a special contribution of EIAR to the Ethiopian National Agricultural Research System. As such, the strategy has been developed in close consultations with a wide range of stakeholders. Such a broad-based participation of key stakeholders is thus believed to ensure shared responsibility and ownership of the strategy.

EIAR has a strong conviction that the strategy will serve a vital document that will: specify the contribution of the research program/theme to the overall achievement of the objectives of Ethiopian NARS; serve as a framework to guide the research program planning and implementation; be used to track record of results and as a reference that can be monitored and reviewed and for mobilizing in resources from national and/or international sources. By having a long-term strategy we specifically aim to focus efforts and fast-track desired outputs as well as achieve research priorities consistency and sequencing.

Indeed, laying down a 15 years plan seems a time too distant to accurately predict. But by scanning and analyzing the national and global trends, and possible future scenarios and signals we believe we have captured at least the coarse portrait of the future. Despite this, however, we by no means claim that it is a complete document. Rather our assumption is that the strategy will serve a live document and remain dynamic to respond to new and emerging problems that can be periodically reviewed and refined in the light of new developments. The full text of the original strategy is much more elaborated than this abridged version and can be retrieved from the EIAR's archive at: http://www. eiar.gov.et

On behalf of EIAR and my own, I would like to extend my sincere thanks to all those who invested their time and energy and, in one way or another, took part in the process of developing the Research Strategy.

Fentahun Mengistu (PhD)
Director General, EIAR

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Cool Season Vegetables Research Strategy

Introduction

Ethiopia is endowed with favorable agro-ecological conditions to cultivate many of the cool season vegetable crops such as garlic, shallot, carrot, beet root, cabbage, Swiss chard and other leafy vegetable crops. Smallholder farmers and some commercial farms produce different vegetables in wide climatic ranges (up to 3000 masl.) of the country under rain-fed and irrigated conditions. The country produces about 852,304 tons of vegetables from a total of about 6.8 million ha which is 1.43% of the total area covered by all crops at national level (CSA, 2013). Out of the 3.7million ha of potentially irrigable land on which fruits and vegetables could be produced only about 250,000 ha of the potentially irrigable land is currently under cultivation.

Vegetable crops can generally be very important source of vitamins, minerals and proteins to a country like Ethiopia where people experience malnutrition due to heavy dependence on cereal. Ethiopians, on average, consume less than 100 g of fruits and vegetables per day, i.e. less than a quarter of the recommended consumption (WHO, 2003 and FAO/WHO, 2004). Several studies also revealed that vitamin A deficiency is a major public health problem in Ethiopia where less than 75% of pre-school age children consume vitamin A rich foods at least three times a week.

In addition, there is a steady increase in demand of different vegetables for export and processing sectors. The country is strategically located to export fresh produce to (Sudan, Somalia, Djibouti), and to the Middle East and the EU-markets. Export of fruits and vegetables increased from 6 to 30 million USD between 2002/03 and 2009/10 from, respectively.

Currently, the horticulture industry is not capable of providing enough nutrition to the people and generating sufficient income from export. Large-scale fruits and vegetable farms were government owned, which produce the bulk of the vegetables and fruits for local consumption. They are not organized and produce low quality products that don't qualify for export. In both cases the production was characterized by low input, poor agronomic management, high pest and disease damage, high post-harvest losses, poor organization, and uncertain markets.

So far, efforts have been made to improve the production system with improved packages of varieties and agronomic practices in major vegetable crops. The effort somehow motivated growers and increased the production of vegetable crops. However, seasonality of production and market problems coupled with high postharvest losses has been discouraging growers. On the other hand, limited research focus, lack of knowledge by growers and consumption habit by consumers have led to scarcity in produces of a wide range of high value fruit and vegetable crops. Therefore, due to the abovementioned problems and the consequent under development of the sector, the demand for fruit and vegetable crops of the non-agricultural Middle East and some neighboring countries have been fulfilled by imports from as far as the South American countries.

It is clear that with the existing situation, the horticulture industry cannot be able to produce as competent products as its competitors from the South America, the North Africa and the Middle East. In order to improve the situation, the government has provided privileges such as provision of 70 percent of the investment capital, duty-free import of farm equipment, and a five year tax holiday to export oriented growers. Consequently, companies such as Jittu horticulture, Ethio-veg fru PLC, Ethio-rose PLC, Genesis Farms, etc. started producing some high value vegetables for export and local consumption. Some flower growers also began diversifying to greenhouse vegetables.

The government of Ethiopia has also set an ambitious five-year growth and transformation plan to increase the production of vegetables and fruits from 1.28 million tons to 5.91 million tons by doubling the average productivity from 84 q to 165 q per ha and expanding land from 152.6 thousand ha to 236 thousand ha in 2014/15 from the base year 2009 (MOFED, 2010).

In order to double the productivity as planned, the number of large and medium size farms producing high value fruits and vegetables has to be increased and should be assisted by the research system to produce competent high quality products that can be exported. Such increase in productivity cannot be achieved by the existing traditional low input horticulture and it has to leave way for intensive production system. Experiences elsewhere in the Middle East, North Africa and neighboring countries such as Kenya have shown that protected culture using tunnels and greenhouses have revolutionized horticultural production and resulted in high value products throughout the year. Therefore, developing the vegetable sub-sector through such long term research and development strategy is vital to effectively utilize the potentials of vegetable crops.

Rationale of the Strategy

The purpose of the strategy is to systematically identify, analyze and prioritize research gaps in the vegetable sub-sector and thereby generate sustainable need based technologies/information that increase productivity and quality of vegetable products for local and export markets. The technologies are targeted to benefit small-scale and commercial growers, agro-industries and consumers.

The strategy was aligned with national strategy of small-scale vegetable growers and the second Growth and Transformation Plan (GTP-II) and contributes to the targets set in these strategies. The strategy is multidisciplinary and considers variety improvement, agronomy/physiology, IPM, mechanization, nutrition and processing, socio-economic and extension. It is stratified into short (5-years), medium (10 years) and long (15 years) terms based on the priority/urgency of the constraints and achievability of solutions.

vision

The vision of the National Cool-season Vegetable Research Program (NCVRP) is to see the research commodity become premium source of information, knowledge and technology and the vegetable sub-sector be able to produce sufficient high quality vegetables for local and export markets and for processing.

Mission
The mission of the NCVRP is to avail proven technologies, information and knowledge on cool season vegetables and support the sub-sector to become competitive source of nutrition, income, foreign currency and raw material for agro-industries.

Goal
The goal of NCVRP is to enhance food and nutritional security and income of all actors in the value chain and supply of raw-material for agro-industries by increasing production and productivity of cool season vegetable crops through availing proven technologies.

Objectives
The overall objective of NCVCP is to develop, adopt and disseminate proven technologies, information and knowledge and thereby contribute towards the betterment of the overall livelihoods of actors in the value chain through increased production, productivity and quality of cool-season vegetable crops.

Guiding principles
The NCVCP will follow the following guiding principles to attain its objective of availing competitive technologies for small and commercial producers.

- Research for development and health of the society;
- Capacity building and modernization of the research system;
- Building and sustaining collaborative research relationships with national and international organizations to share/acquire information/knowledge and resources;
- Establish multidisciplinary team and conducive research environment;
- Public-private partnership with stakeholders involved in the value chain of the sub-sector ;
- Environment and health consciousness and
- Due considerations to cross-cutting issues such as gender equity and climate change.

Importance of the sector

Agriculture
Ethiopia has different agro ecological zones with adequate irrigation water, favorable climatic conditions and high potential for development of cool season vegetable. Generally, Cool Season vegetables grow well in areas with average temperature of 15-20^{o}C. Tepid to cool moist mid highland (M2), Tepid to cool sub-humid mid-highland (SH2) and Tepid to cool sub-moist mid-highland (SM2) agro-ecological zones have huge potentials for the production of cool season vegetables.

Alliums (garlic and shallot)
Garlic and shallot are among the major vegetables that are grown in most part of the country. Garlic is adapted to cool climate regions of Ethiopian highlands and thrive best at average temperature of 12 to 24 ^{o}C. Similarly, shallot is mostly grown in the mid-and

high-altitude areas ranging from the highlands of Arsi and Bale (2400 meter above sea levels; masl) to the lowlands of Kesema and Shenkora (1600 masl) and it is also well adapted to different soil types. Ethiopia is considered as the center of diversity for shallot. Significant genetic variability for important agronomic and morphological traits was reported. Garlic has been produced for a long time in Ethiopia; however, as it is a vegetatively propagated crop, its genetic variability is presumed to be narrow. In 2014/15 growing season about 1.8 million farmers produced a total of 934.8 thousand tons of garlic from an area of 9.3 thousand ha with productivity of 10.1 t/ha. Likewise, about 2.3 million tones of onions (onion and shallot) was produced from about 22.8 thousand ha. This amount was produced by 705.9 farmers with an average productivity of 10.1 t/ha (CSA, 2015).

Crucifers (Ethiopian kales, cabbage, cauliflower broccoli and radish)

Ethiopian kale, head cabbage, cauliflower and broccoli all belong to the same species, *Brassica oleracea* L., are cool season vegetables that thrive well under optimum temperature of between 15 and 18 ^{0}C, (Maynard and Hochmuth, 2007). Thus, they are best adapted to the highlands of Ethiopia. Among cole crops, Ethiopian kale and head cabbage are the two most important leafy vegetables in Ethiopia and they are cultivated as garden crops in most part of the country. Cauliflower and broccoli are recent introductions to the country and their production is mostly confined to commercial farms.

The country is assumed to have adequate amount of genetic variability for Ethiopian cabbages. For instance Ethiopia is considered to be the center of diversity for Ethiopian Mustard ("Yabesha gomen") which is a natural amphidiploid derived from hybridization between Ethiopian kale (*B. oleracea*) and "senafich" (*B. nigra*). However, so far there are no detail reports on the genetic diversity of Ethiopian kale ("yeguragie gomen"). Head cabbage is among the exotic vegetables that are introduced to the country. Two old varieties, namely Copenhagen market and early durum head are the major head cabbage varieties that have been produced in most cabbage growing areas of the country.

About 364 thousand farmers produced 28,919.9 tones of cabbage from 4.5 thousand ha of land while about 3.4 million farmers grow Ethiopian cabbage on about 31.4 thousand ha of land with production of 3.3 million tones (CSA, 2015). However, compared to other countries, both head cabbage and Ethiopian cabbage have low productivity of 6.4 and 10.4 t/ha, respectively.

Carrot

Carrot (*Daucus carota* L.) is one of the widely produced and consumed root vegetables in Ethiopia. Carrot is a cool-season vegetable with some tropical types that can tolerate quite high temperatures. It requires 15 to 20°C temperature for its optimum growth. It is well adapted to mid- and high-altitude areas and produced under rain fed and irrigation conditions. Similar to most of cool season vegetables, carrot is not indigenous to Ethiopia, there are only very few improved varieties that are mostly imported from other countries. Based on CSA (2015) 159 thousand carrot growers covered about 3.7 thousand ha of land

with the production of 14.3 thousand tones where the productivity stood very low at 3.9 t/ha.

Chenopodacea and others (lettuce, asparagus, radish)

Vegetables like beet root, Swiss chard and spinach belongs to the family Chenopodacea which prefers cool weather for their optimum growth. Swiss -chard grows best at temperatures ranging from 7 to 24 °C. Similar to the cabbages, they are being produced as home-garden vegetables. Detroit Dark Red and Ford Hook Giants are the most popular beet root and Swiss-chard varieties, respectively. In 2014/15 main season a total 18.2 thousand tons of beetroot was produced by about 333 thousand holders from an area of 1.9 thousand ha with average a productivity of 9.3 t/ha. Likewise, about 78 thousand growers cultivated a combined sum of 310.7 ha of land and harvested 3,29 tons of Swiss-chard with productivity of 1.6 t/ha.

Table1. Total production (000 t) of major vegetable crops in Ethiopia between 2004 and 2013

Crop	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	% increase (2004-13)
Ethiopian kale	213.6	262.5	180.8	159.2	238.4	281.6	274.2	331.6	323.2	371.0	173.7
Garlic	135.4	196.7	107.2	68.3	103.5	156.0	179.7	128.4	124.0	222.5	164.4
Onions (onion and shallot)	216.7	229.7	175.9	178.5	175.1	148.9	169.3	236.9	328.2	219.2	101.2
Head cabbage	8.6	15.2	12.9	10.1	11.8	24.1	20.4	19.5	43.5	23.2	270.8
Beet root	14.1	16.5	16.3	14.4	16.9	20.1	10.1	14.4	24.5	16.8	119.5
Carrot	10.0	17.9	6.9	6.7	na	13.5	18.2	12.3	13.6	5.1	50.9
Swiss chard	1.1	0.7	na	na		0.7	0.6	1.0	1.7	0.3	30.6

Food and Nutrition

Vegetables have been used in many parts of the world as sources for ranges of nutrients. They provide excellent sources of nutrients, such as protein, vitamins, minerals, phyto-nutrients and fiber, as well as non-nutrient phytochemicals such as sulfur-containing compounds (Table 2). A number of studies indicated that consumption of adequate amounts of vegetables may have disease-preventive properties. Hence, the demand for varieties of vegetables expanded in most parts of the world. Similarly, in Ethiopia the trend of vegetable consumption is increasing. However, the daily per capita consumption of vegetables is very low compared to the recommended value and hence vitamin deficiency remains as one of major public health problems in Ethiopia. Therefore, increasing production and consumption of diverse cool season vegetables is one of the major integral parts of nutrition sensitive interventions.

Importance in the national economy

Food security, income generation and employment

The vegetable sub-sector is one of the important sub-sectors of the Ethiopian economy. The high productivity and short growing period of vegetables as compared to cereals and other crops enables production of up to three cycles per year making vegetables the most preferred crops for irrigated agriculture. Thus, the return from vegetables per unit area is several folds higher than major cereals. Indigenous vegetables such as Ethiopian kale are part of the culture of the Ethiopians and contribute to food security and survival to the rural population during adverse drought. Production of cool season vegetables has increased by 30 to 200 percent (Table 1) with the maximum growth recorded by head cabbage. The country produces 4.8 million tons of cool season vegetables on 51 thousand ha of land involving more than six million holders. Apart from being source of food and income for the growers it creates employment opportunities for those who are involved in all aspects of the business (propagation, transporting, trading and processing of vegetable products) along the value chain. However, the current trend is not in parallel with the country's export, employment and nutrition requirements. Hence, there is still a huge potential for expansion of cool season vegetables and increasing productivity of cool season vegetable crops in the country.

Table 2.Nutritional value of some cool season vegetable crops

	Unit	Cabbage	Broccoli	Carrot	Swiss chard	Cauliflower	Beet	Radish	Asparagus	Lettuce
Energy	kcal	25	34	41	19	25	43	16	20	15
Carbohydrates	g	5.8	6.64	9.58	3.74	4.97	9.56	3.40	3.38	2.87
Protein	g	1.3	2.82	0.93	3.27	1.92	1.61	0.68	2.20	1.36
Total Fat	g	0.1	0.37	0.24	0.20	0.28	0.17	0.10	0.12	0.15
Cholesterol	Mg	0	0	0	0	0	0	0	0	0
Dietary Fiber	Mg	2.50	2.60	2.8	1.6	2.0	2.80	1.6	2.1	1.3
Folates	µg	53	63	19	14	57	109	25	52	38
Niacin	mg	0.234	0.639	0.983	0.400	0.507	0.334	0.254	0.978	0.375
Riboflavin	mg	0.040	0.117	0.058	0.090	0.060	0.057	0.039	0.141	0.080
Thiamin	mg	0.061	0.071	0.066	0.040	0.050	0.031		0.143	0.070
Vitamin A	IU	98	623	16706	6116	0 IU	33	7 IU	5.6	7405
Vitamin C	mg	36.6	89.2	5.9	30	48.2	4.9	14.8	756	9.2
Vitamin E	mg		0.17		1.89	0.08	0.04	0	1.13	0.29
Vitamin K	µg	76	101.6	13.2	830	15.5	0.2	1.3	41.6	126.3
Sodium	mg	18	33	69	213	30	78	39	2	28
Potassium	mg	170	316	320	379	299	325	233	202	194
Calcium	mg	40	47	33	51	22	16	25	24	36
Iron	mg	0.47	0.73	0.30	1.80	0.42	0.80	0.34	1.14	0.86
Magnesium	mg	12	21	12	81	15	23	10	14	13
Manganese	mg	0.160	0.210	0.143	0.366	0.155	0.329	0.069	0.158	0.250
Phosphorus	mg	26		35	46				52	29
Zinc	mg	0.18	0.41	0.24	0.39	0.27	0.35	0.28	0.54	0.18

Export market and foreign currency earning

Cool season vegetables have been exported to neighboring African countries (Sudan, Somalia, Djibouti), the Middle East and the EU and generated about 6 million USD foreign currency in the year 2015. Djibouti and Somalia are the major market destinations, importing about 99 % of the total volume of cool vegetables exported from Ethiopia (Fig. 1). However, considering the potentials that the country possesses, the export value generated from these crops is very low compared to other horticultural crops. Therefore, the sub-sector should be modernized so as to produce and export sufficient amount and good quality produces.

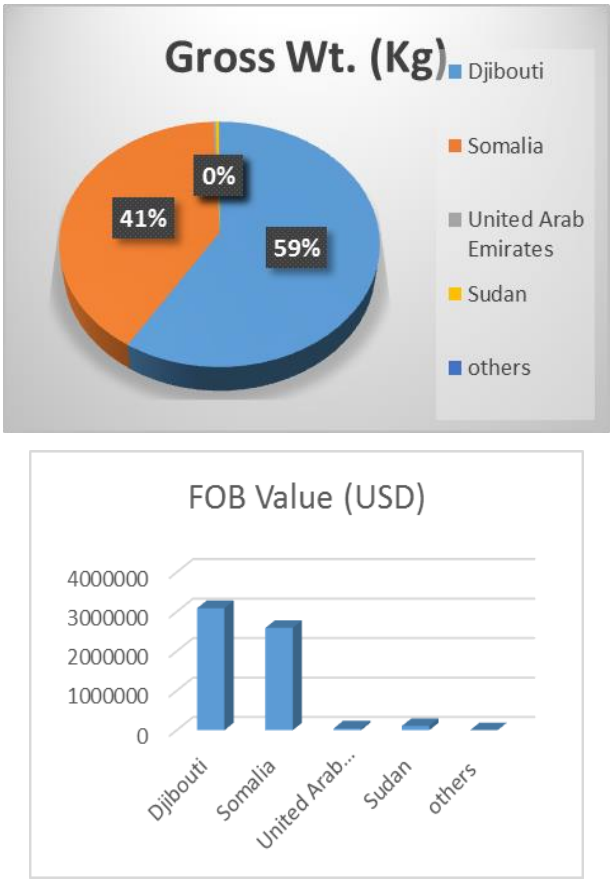

Figure1. Export of cool season vegetables in quantity and value

Environmental Sustainability

In Ethiopia, growing field crops is the most dominant agricultural activity compared to Vegetable production. Hence, introducing vegetables into the farming system as major companion crops that can be grown in rotation with different field crops or as an intercrop with perennial plants has significant contribution for sustainable agricultural production. Generally, vegetables have high biomass compared to other field crops; therefore, continuous vegetable production can serve as a sink for atmospheric carbon. Moreover, their suitability for organic production practices has a potential for sequestering high amount of carbon into the soil. In addition, even though, there is high post-harvest lose their suitability for waste management can reduce carbon emission.

However, the use of synthetic fertilizers and pesticides is comparatively high in the conventional vegetable production system. Hence, assessment of the contribution of vegetable production to environmental sustainability is important. Development of integrated nutrient and pest management technologies through the application of Good Agricultural Practices will create environmentally sound vegetables production system.

Assessment of External and Internal Environments

Assessment of External Environments
Operational External Environment

Clients/Users

The major clients include the Ministry of Agriculture and Natural Resources, the Regional Offices of Agriculture and Natural Resources, farmers and farmers' organizations, and private sector (commercial vegetable growers). These stakeholders which play a key role in research and development of CVCs also include actors in the value chain of cool season vegetables including the input suppliers, traders, transporters, agro-processors and consumers across.

Partners
National

The major national partners involved in the R&D of CVCs are Regional Agricultural Research Institutes and their affiliated agricultural research centers, higher learning institutions and NGOs. Collaborating centers include Kulumsa, Holeta and Bore Agricultural Research Centers (ARCs) of Oromiya RARI, Debre Brehan and Fogera ARC of Amhara RARI; Axum ARC of Tigray RARI; Endebir ARC of Southern RARI. Additional centers in the mid- and highlands of Ethiopia will be included as deemed necessary. Agriculture faculties of Haramaya, Jimma, Debre Markos, Arisi, and Ambo universities will also be the major partners in the R&D of CVCs.

In addition, partners also include Ethiopian Food, Beverage and Pharmaceuticals Development Institute, Ministry of Finance and Economic Development (MoFED), Ministry of Science and Technology (MoST), the Ethiopian Biodiversity Institute (EBI),

Agricultural Transformation Agency (ATA), Government Procurement Agency (GPA), Central Statistical Agency, National Meteorological Services Agency, Federal Cooperative Agency (FCA), Regional Cooperative Offices (RCOs), Ministry of Trade (MoT), Ministry of Industry (MoI), the Ministry of Foreign Affairs (MoFA), private sector, Non-governmental organizations, and agricultural professional societies.

International

International partners and collaborators that have key roles in R&D of CVCs include Asian Vegetable Research and Development Center (AVRDC)/ the world vegetable center, Nutrition Research Institute (NRI), International Plant Genetic Resource Institute (IPGRI), Korean Project for International Agriculture (KOPIA), Korean Africa Food and Agriculture Cooperation Initiative (KAFACI) for International Center for Inset Physiology and Ecology (ICIPE), ASARECA, etc. The roles of each of these institutes are noted in Appendix Table 2.

Assessment of Internal Environments

The assessment of internal environments of the Program analyses and identifies the strengths and weaknesses of the program and of EIAR in relation to attaining its objectives. Currently, the national research on CVCs is coordinated from DebreZeit Agricultural Research Center while other Federal and regional agricultural research centers collaborate with the coordinating center to undertake research that have national importance. The collaborating centers undertake adaptation of research to their agro-ecologies and can also initiate research relevant to their localities. The major centers responsible for CVCs research are Debre Zeit, Kulumsa, Holeta, Debre Brehan, Bore, Fogera agricultural research centers. Haramaya, Jimma, Hawassa and other universities also collaborate in the research.

Capacity Building

Human

The National Cool Season Vegetable Crops Program is a new program established due to the division of the Vegetable Crops Program into cool and warm season vegetables. Hence, its human resource in all disciplines and across different centers is a few in number and most are at BSc lower level of training. Therefore, the Program needs well trained researchers and technical staff at the coordinating and collaborative centers.

Physical

The NCVCP, as a recently established program, has very limited physical capacity in terms of office, laboratory, greenhouse and irrigation/fertigation. Moreover, field facilities, vehicles, agricultural machinery, consumables, etc are limited. In addition, testing sites and sub-centers under various research centers have also limitation in number, size, facility (especially irrigation) and representativeness.

Financial

The vegetable research in general had inadequate financial resources. Financial release system and procurement process were sluggish and has limited smooth operation of the research.

Intra- and Inter- disciplinary Integrations, Complementarities and Synergies

Intra- and inter- disciplinary integrations, complementarities and synergies were weak due to inadequate coordination, linkage, communication and database management. Moreover, applied research undertakings in areas such as socio-economics, soil, physiology, food science, crop protection and agricultural mechanization have been limited.

Technologies Available

The Cool Season Vegetable Crops Program has been undertaking research on garlic and shallot and succeeded in releasing five garlic varieties and three vegetatively propagated and two seed propagated shallot varieties along with their management practices and control methods of major pests. Research on other cool-season crops was limited to testing and adapting of high yielding and high quality vegetables in collaboration with private seed companies. Consequently, eight cvs of cabbage, two cvs of cauliflower, two cvs of broccoli and eleven cvs of lettuce were registered for local as well as export markets.

Gaps

Although efforts have been made to improve vegetable production of some cool season vegetable crops with improved technologies in shallot and garlic, research on other cool season crops was meager. Moreover, apart from some attempts on variety development and cultural practices, research on cropping system, integrated pest, disease and weed management, food science, post-harvest technology and nutrition, agricultural mechanization, technology multiplication and seed system and technology popularization and marketing were not give due attention.

Organization, Implementation and Geographic Coverage

Organization and Geographic Coverage

Currently, research on cool season vegetables is coordinated for Debre Zeit Agricultural Research Center. Kulumsa, Holeta, Debre Brehan ARC and Haramaya University were involved in the CVCs research. However, inter- and intra-institutional coordination was weak. Research centers and sub-centers in cool agro-ecologies will be included in the near future.

Table 3. Assessment of external (Opportunities, challenges) and internal (strength and weakness) of Cool Season Vegetable Crops

Thematic area	Internal Environment/situation		External Environment/situation	
	Strength	Weakness	Opportunities	Challenges
Breeding and Genetics	- Availability of germplasm of some CVC (garlic, shallot and Ethiopian kale) - Possibility of de-hybridizing introduced hybrid cvs	- Lack/limited germplsm of most of CVCs (cole crops, lettuce, beet root, radish, etc) in the country that suits different purposes. - Lack of strong relations with international research organizations and researchers - Limited number of research centers in the highlands that meet chilling requirements - Lack of diverse genetic base of CVCs that can suite different agro-ecologies - Weak linkage of the Commodity to international organizations. - Lack of research facilities and highly trained staff on biotechnology	- Possibility of introducing cvs of CVC that are royalty free from different research institutes and countries - Presence of some companies that introduce hybrid cvs - Diverse agro-ecologies for the production of different CVCs - Encouraging policy and public investment for introduction and adaptation of CVCs	- Difficulty of introducing sufficient quantity of germplasm - Most commercial cvs are hybrids that cannot be used directly. - Difficulty to produce seeds in most agro-ecologies and the need for extended breeding process - Diverse agro-ecologies require specific improved varieties - Ever changing demand of the sub-sector especially for export market - Climate change and increased biotic and abiotic stresses
Agronomy physiology	- Availability of research centers working on at different AEZs	- Lack of crop and AEZ specific full agronomic packages - Limited knowledge and skill in production agronomy/physiology of most CVCs (cole crops and other leafy vegetables) - Lack of organic production technologies (Integrated nutrient management, bio-fertilizers, etc.)	- Possibility of adaptation of technologies on agronomy and physiology - Diverse AEZs for different production systems and year round production - Increasing trend of intensive farming (urban agriculture, greenhouse farming) and emerging commercial sector.	- Technological and knowledge gaps to adapt basic and applied knowledge in field production - Complex physiology and high tech requirement of CVCs - **M**ore advanced private sector than research centers - Limited kinds and low quality inputs (fertilizers) and lack of quality control system
Crop Protection	- Availability of pest management practices for several major pests of major CVCs - Continuous registration of new agro-chemicals	- Lack of full-fledged IPM options on major pre and post-harvest (PPH) pests of CVCs - Limited information on biology and ecology of major pests of CVCs - Inadequate research on bio-control options of CVCs - Lack of modern protection research facilities and highly trained technical staff	- Possibility of acquiring IPM options from different research institutes and countries - Diverse fauna and flora in the country - Encouraging policy and public and private investment on protection	- IPR issues and absence of policy for the regulation of bio-control options - Frequent pest outbreaks due to changing environment and tropical nature of the country - Ineffective quarantine/regulatory system and surveillance - Introduction and spread of pests due

Thematic area	Internal Environment/situation		External Environment/situation	
	Strength	Weakness	Opportunities	Challenges
				to global increase in product and seed trade of CVCs
Irrigation water management	- Availability of irrigation water potentials at various research centers - Experience in irrigation water management on CVCs	- Crop and variety specific water requirement and irrigation scheduling are not available - Lack of research on different water efficient irrigation systems for different AEZs	- Vast potential surface and ground water resources - Government focus on irrigated agriculture - Availability of efficient irrigation water management technologies worldwide	- Global warming, high variability in surface water resources due to frequent drought cycle - Salinity associated with poor water quality and irrigation practices
Post-harvest Management (PHM)	- Central and satellite labs for quality and nutritional analysis set by EIAR	- Limited PHM and value addition technologies, nutrient and quality analysis of CVCs; - Lack of highly trained research staff and modern post-harvest and quality research facilities.	- Possibility of acquiring technologies related to PHM and value addition; - Favorable policy incentives for agro-processing industries for export market and small-scale enterprises; - Common certification setting (EHPEA); - Increased local demand for PHM and - Availability of private labs.	- Post-harvest technologies have high investment costs; - Absence of local-GAP, strict global food safety standards and costly certification process; - Lack of investment in sub-sector specific infrastructures and logistics.
Agricultural Mechanization	- Existing workshop meant for development of small-scale tools	- Lack well-equipped workshops and well trained engineers to copy/adopt and design/develop pre- and post-post-harvest tools/machines	- Availability of technological options for pre- and post-harvest (seeding/planting, harvesting, packing and processing); - Emerging engineering industries	- Expensive technologies unaffordable by stallholder growers; - Weak financial capability of small-scale farmers to acquire technologies.
GIS and Agro meteorology	- GIS and agro meteorology research units are established in most research centers	- Lack of crop suitability map, seasonal forecast and geospatial analysis information for production CVCs; - Lack of highly trained research staff and modern facilities for GIS and meteorology research.	- Advanced GIS and agro-meteorology technologies are available worldwide	- Wide technological and research capacity gaps and expensive technologies; - Climate change (global warming) is limiting production of CVCs under different AEZs.

Thematic area	Internal Environment/situation		External Environment/situation	
	Strength	Weakness	Opportunities	Challenges
Technology multiplication	- Inception of seeds/PM production of CVCs at major research centers; - TC labs are available in major centers to produce disease free nucleus seed/planting material.	- Lack of facility and skilled human power to undertake research and production of breeder/pre-basic seeds of CVCs; - Lack of adapted TC protocols and insufficient inputs and facility of TC labs.	- High seed/planting material demand for improved technologies of CVCs; - Availability of commercial micro-propagation techniques	- Lack of public or private commercial enterprises involved in seed production of CVCs; - Dependence on import of hybrid seeds; - Lack of certification and regulatory schemes for authenticity, phyto-sanitory and quality seedlings
Agricultural Economics, extension and gender	- Availability of technological packages for major CVCs (shallot, garlic) - Experience in technology demonstration and popularization - Availability of human resource capacity to undertake research	- Insufficient planting material for vegetatively propagated crops (garlic). - Weak linkage between research, extension and stakeholders - Limited popularization on consumption and production of CVCs - Inadequate information on value chain of CVCs	- High demand of CVCs both for local and export markets - Existence of extension system (GOV & NGOs) and supportive technology promotion policy - Expansion and improvement of communication, physical infrastructures - Geographical proximity to export markets, cheap labor force	- Conventional and low input small-scale farmers - Weak marketing infrastructure and system of vegetable products - Weak linkage among extension actors for concerted action

Benchmarking

Production and productivity of major cool season vegetable crops was compared with countries with highest production (China and India) and productivity, and the world. In terms of production, Ethiopia's share of production of the major cool season vegetables is negligible and it is many folds lower than that of the major producers (Table 4).

The wide productivity gap between the bench-marked nations and Ethiopia is mainly because of sufficient number of highly trained researchers at each discipline, and higher level of technological advances in facilities, acquisition and maintenance of diverse gene pool, use of biotechnological tools geared toward generation of hybrid varieties, protected horticulture (advanced climate control and fertigation systems). Therefore, step by step building of capacity of researchers and facilities is unequivocal to narrow the productivity gap.

Table 4. Comparison of area, production and productivity of major cool season vegetables of Ethiopia with major producers and the world

Crop	Country	Productivity (t/ha)		Productivity ratio	Percent increment at each phase	
		National average	Research		Research	National
Onions (onion and shallot)	Ethiopia	10.5	35		20	50
	China	22.0		2.1		
	India	16.0		1.5		
	USA	54.6		5.2		
	Kenya	11.2		1.1		
	World	19.4		1.9		
Cabbages	Ethiopia	7.1			20	50
	China	33.5		4.7		
	India	22.9		3.2		
	South Korea	71.2		10.0		
	Kenya	31.6		4.4		
	World	29.4		4.1		
Garlic	Ethiopia	11.0	8.5		20	50
	China	24.6		2.2		
	India	5.1		0.5		
	USA	18.1		1.7		
	S. Korea	14.1		1.3		
	Kenya	6.0		0.6		
	World	16.9		1.5		

Strategic Issues Facing the Cool Season Vegetables Program

The major strategic thematic areas identified for the Cool Season Vegetables Program include: (1) Genetics and breeding; (2) Agronomy and physiology, (3) Crop protection (4) Post-harvest and quality, (5) Technology multiplication and seed research, (6) Agricultural economics, research extension and gender and (7) Capacity building. The strategic issues are presented under each thematic area (Table 5). Strategic issues could also be addressed under different cross-cutting themes (Biotechnology, Agricultural mechanization, Soil and water management, GIS and Agro-meteorology, knowledge management (ICT), etc.). The crosscutting themes can be relevant across themes in the Program.

Strategic Issues

Table 5.Strategic issues under different thematic areas on cool season vegetables program

No.	Thematic areas	Strategic issues
1	Genetics and Breeding	• Limited germplasm and narrow genetic base of major cool season vegetables o Narrow genetic base of exotic CVCs - low efforts in introducing germplasm of exotic cool season vegetables and dependency on introduced commercial hybrid materials o Limited local number of germpasm collections, characterization and maintenance of traditional CVCs
		• Lack of appropriate germplasm management system o Lack of organized germplasm maintenance o Lack of advanced techniques of germplasm maintenance
		• Low productivity of major CVCs and lack of varieties for most traditional CVCs o Limited/lack of improved (productive, resistant/tolerant and high nutrition) varieties o Application of traditional breeding methods (selection) in shallot and garlic o Little research effort in variety development of important traditional vegetables o Lack of use of biotechnological tools for variety development
2	Agronomy and physiology	• Inadequate information on recommendations of agronomic packages (fertilizer rates, application methods, seed rates, spacing, planting and harvesting dates) • Lack of appropriate vegetable nursery management practices • Lack of information on appropriate nutrient and water management of CVCs • Lack of improved technologies on organic vegetable production • Lack of appropriate seed production technologies of CVCs • Lack of cropping systems studies
3	Crop protection	• Limited information on major pests of major CVCs • Lack of IPM technologies for CVCs • Low consideration to organic production of CVCs
4	Post-harvest and quality	• Lack of information on the nutritional values of traditional cool season vegetables • Poor post-harvest handling and value addition of cool season vegetable produces • Lack of information on food safety of CVCs in relation to pesticide application and waste water use

No.	Thematic areas	Strategic issues
5	Technology multiplication and seed research	• Lack of sufficient seed/planting material of released varieties • Lack of information (biology, physiology) of seed/planting material of CVCs
6	Agricultural-economics, research extension and gender	• Lack of coordinated seed/planting material production of CVCs • Weak efforts on dissemination of improved CVCs • Limited market and value chain information on CVCs • Limited effort on mainstreaming of gender on production and marketing of cool season vegetables
7	Capacity building	• Lack of skilled human power in different disciplines • Lack of modern field and lab research facilities • Insufficient budget allocation

Strategic Interventions

Table 6 .Strategic issues in different thematic areas and their interventions in the short, medium and long-term.

Thematic areas	Strategic issues	Short- term intervention (2017-2021)	Medium-term intervention (2017-2026)	Long-term intervention (2017-2031)
Genetics and Breeding	Germplasm genetic enhancement	• Undertake and organized local collection and characterization of the existing diversity of traditional cool season Vegetables; • Introduce and characterize hard neck and soft neck garlic germplasm; • Characterize the existing garlic germplasm using molecular markers; • Develop double haploid breeding population of head cabbage; • Introduce, evaluate commercial hybrid varieties and generate segregating population of exotic cool season vegetables	• Introduce international germplasm; • Molecular characterization of traditional cool season vegetables • Develop breeding lines from commercial hybrid varieties • Develop and characterize double haploid breeding population for major Brassica cool-season vegetables • Adopt and optimize mutation breeding techniques and generate mutant genotypes in garlic	• Introduce international germplasm • Association mapping using QTLs analysis for major traits on traditional cool season vegetables. • Genotyping of the existing germplasm with molecular markers (MM) • Develop mutant genotypes
	Germplasm management	• Optimize efficiency of the available germplasm management system through experience sharing with other research programs; • Strengthen linkage with EBI to consider maintenance of vegetable germplasm.	• Introduce and adapt appropriate and efficient methods of germplasm management system; • Establish and strengthen linkage with international and germplasm banks.	• Capacitate the existing germplasm management system with the help of biotechnological tools (tissue culture and MM)
	Productivity of major CVCs	• Develop high yielding OPVs from existing genetic resources • Introduce and adapt, high yielding and disease resistant OPVs • Introduce and register high yielding and disease resistant commercial hybrids	• Strengthen variety development from local collections; • Dedevelop high yielding and disease resistant hybrid shallot cvs through	• Iintroduce and develop of OPVs and hybrid varieties; • Develop an MS system for shallot hybrid; • Assist variety development efforts with application of

Thematic areas	Strategic issues	Short- term intervention (2017-2021)	Medium-term intervention (2017-2026)	Long-term intervention (2017-2031)
		• Develop breeding lines	conventional methods; • Introduce Male Sterility MS system to develop shallot hybrids and • Introduce and registerr high yielding and disease resistant commercial hybrids.	biotechnological tools (eg. MAS) and • Introgression of Cole crops
Agronomy and physiology	Vegetable nursery management	• Introduce and adopt appropriate nursery management practices; • Develop agronomic packages on conventional and semi-advanced vegetable nursery management.	• Introduce and adopt appropriate nursery management practices • Develop agronomic packages on commercial/modern nursery management	• Strengthen introduction and development of advanced commercial nursery management practices
	Agronomic packages	• Introduce and adapt appropriate agronomic practices; • Update and develop agronomic packages for optimum productivity and quality of produces of CVCs under different production systems (conventional, urban) • Assess existing farming systems with focus on CVCs	• Introduce and adapt appropriate agronomic practices; • Update and develop agronomic packages for optimum productivity and quality of produces of CVCs .under different production systems (conventional, commercial/modern, urban) • Undertake cropping systems study on major CVCs	• Strengthen introduction and development of agronomic practices • Develop and incorporate appropriate CVCs cropping systems to the farming systems •
	Nutrient and water management	• Assess existing nutrient and water management systems; • Introduce and adapt, and develop viable nutrient and water efficient practices (fertigation, foliar nutrient application) for major CVCs.	• Develop viable nutrient and water efficient practices (fertigation, foliar nutrient application) for traditional CVCs; • Assess the influence of	• strengthen development of viable nutrient and water efficient practices (fertigation, foliar nutrient application) for traditional CVCs

Thematic areas	Strategic issues	Short- term intervention (2017-2021)	Medium-term intervention (2017-2026)	Long-term intervention (2017-2031)
			abiotic stresses on growth and development and yield of major CVCs.	
	Organic vegetable production	• Assess existing Good Agricultural Practices (GAP) organic production technologies; • Identify and study nutrient compositions of different organic fertilizers and their sources.	• Develop organic production packages for major CVCs; • Align production of CVCs to Good Agri. Practices	• Align production of CVCs to Good Agri. Practices organic production packages for major CVCs
	Seed production technologies	• Study the phenology of biennial CVCs; • Map suitable AEZs appropriate for major CVCs using Agro-met and GIS tools and • Develop appropriate agronomic/physiology packages for seed production of CVCs	• Develop appropriate agronomic/physiology packages for seed production of CVCs	• Strengthen development of appropriate agronomic/physiology packages for seed production of CVCs
Crop Protection	Major pests	• Survey on major pests of CVCs • Generate information on biology ecology and epidemiology of major pests of CVCs	• Conduct race/species analysis of major pests of CVCs using biotechnological tools; • Optimize biotechnological methods of race/species analysis	• Strengthen race/species analysis of major pests of CVCs using biotechnological tools.
	IPM technologies	• Introduce and adapt suitable cultural and chemical control methods; • Develop appropriate cultural and chemical control methods for major diseases and pests of major CVCs and • Introduce adapt biological pest control methods of major CVCs	• Introduce and adapt, and develop appropriate IPM methods for major diseases and pests of major CVCs under conventional, • commercial and organic production systems	• Sstrengthen development of appropriate IPM control methods for major diseases and pests of major CVCs under conventional, commercial and organic production systems
Post-harvest and quality	Nutritional value	• Conduct nutritional analysis and update information on the nutritional	• Incorporate nutrition and quality parameters to	• Conduct research on post-harvest physiology of

Thematic areas	Strategic issues	Short- term intervention (2017-2021)	Medium-term intervention (2017-2026)	Long-term intervention (2017-2031)
		compositions of traditional CVCs	develop highly nutritious varieties	produces in relation to quality and nutritional values
	Poor post-harvest handling and value addition	• Assess and update the existing post-harvest handling methods for major CVCs • Update information on shelf-life of produces of the available varieties	• Introduce and adopt better post-harvest handling methods (packaging, processing, treatment) • Develop semi-processed products (dehydrated products, juice/extracts, pickles)	• Strengthen ddevelopment of better post-harvest handling methods (packaging, processing, treatment) • strengthen development of semi-processed products (dehydrated products, juice, pickles)
	Food safety	• Generate information on the extent of pesticide and sewage water use for CVCs production.	• Execute research on influence of urban wastes and pesticides on human and animal health	• Develop technologies and information on safe use of pesticide and urban waste
Technology multiplication and seed research	Seed technology	• Identify seed quality problems and device ways to improvement; • Generate information and technologies on seeds of CVCs (biology, health, treatment, germination) and • Introduce and adopt advanced technologies for the development of disease free planting material (Tissue culture) of garlic.	• Introduce advanced biotech seed/planting material testing methods (quality and health); • Introduce and adopt advanced technologies for the development of disease free planting material (Tissue culture) major CVCs and • Develop seed processing and handling techniques.	• Strength and advancement of seed testing and disease free planting material production methods of major CVCs • Strengthen and modernize seed processing and handling techniques
	Seed and planting material	• Study existing seed system of CVCs; • Identify and adopt good experiences of technology multiplication from the existing systems and • Multiply high quality breeder, pre-basic seeds of major CVCs	• Introduce and adopt viable technology multiplication experiences to the existing system • Multiply high quality breeder, pre-basic seeds of major CVCs	• Assist technology multiplication effort through implementation of biotechnological tools (tissue culture)

Thematic areas	Strategic issues	Short- term intervention (2017-2021)	Medium-term intervention (2017-2026)	Long-term intervention (2017-2031)
Agri. economics, research extension and gender	Coordination in seed/planting material production	• Organize farmers, youth, women groups and enable them produce high quality seeds/planting material of shallot, garlic and carrots • Develop and update CVCs technology extension packages • Promote integrated technology demonstration and knowledge sharing	• Organize farmers, youth, women groups and enable them produce high quality seeds/planting material of Cole crops, lettuce, Swiss chard • Continue developing and updating CVCs technology extension packages • Continue promoting integrated technology demonstration and knowledge sharing	• Establish seed certification system for CVCs • Continue developing and updating CVCs technology extension packages • Continue promoting integrated technology demonstration and knowledge sharing
	Dissemination of improved technologies	• Demonstrate and popularize improved technologies of cool season vegetables	• Implement clustering approach for efficient demonstration and pre-scaling of improved technologies of CVCs and sustain technology dissemination	• Continue strengthening implementation of cluster approach for the dissemination of the improved technologies
	Marketing	• Conduct value chain analysis for major cool season vegetables (garlic, shallot) in major growing areas	• Conduct value chain analysis for major cool season vegetables in major growing areas	• Conduct value chain analysis for major cool season vegetables in major growing areas
	Gender mainstreaming	• Promote gender main streaming and develop working modality to strengthen the participation of women and youth in CVCs research and promotion	• Promote gender main streaming and develop working modality to strengthen the participation of women and youth in CVCs research and promotion	• Promote gender main streaming and develop working modality to strengthen the participation of women and youth in CVCs research and promotion
Capacity building	Lack of skilled human power in	• Recruit competent professionals, train each in their respective disciplines and	• Continue recruiting competent professionals,	• Continue recruiting competent professionals, train each in

Thematic areas	Strategic issues	Short- term intervention (2017-2021)	Medium-term intervention (2017-2026)	Long-term intervention (2017-2031)
	different disciplines	upgrade thorough experience sharing; • Create good working conditions and incentive mechanisms to retain researchers.	train each in their respective disciplines and upgrade thorough experience sharing; • Continue creating good working conditions and incentive mechanisms to retain researchers.	their respective disciplines and upgrade thorough experience sharing; • Continue creating good working conditions and incentive mechanisms to retain researchers
	Lack of modern research facilities	• Build agronomy/physiology labs, irrigation and field research facilities in major research centers; • Provide vehicles for efficient mobilization and • Establish sub-centers suitable for seed production of CVCs.	• Build tissue culture labs and modern post-harvest facilities in major research centers; • Equip labs with modern biotech equipment.	• Build basic labs and post-harvest facilities in collaborating centers research centers
	Insufficient budget allocation	• Allocate sufficient budget and improve the finance/ procurement system; • Compete for external fund.	• Allocate sufficient budget and improve finance/ procurement system; • Compete for external fund.	• Allocate sufficient budget and improve finance/procurem;ent system • Compete for external fund.

Appendix Table 1.Stakeholders/collaborators of the research sector

No	Stakeholders/collaborators	Role
1	Ministry of Agriculture and Natural Resources	Develop, coordinate and implement national horticultural development strategies and policies, packaging new technologies and dissemination.
2	Regional Bureau of Agriculture and Irrigation Development Authority	Develop, coordinate and implement regional horticultural development strategies and policies, packaging new technologies and dissemination.
3	Higher Learning and Regional Research Institutions	Collaborate in national research and adapt/develop, release technologies/information specific to the region, multiply and demonstrate.
4	EBI	Germ plasm exchange, conservation and maintenance for research, collaborating in research
5	GO's,(ATA,EHDA, EHPEA)	Enhance and support capacity in vegetable development program, training, advisory services
6	Ethiopian Seed Growers and Processors/Agricultural Input Supply Enterprise/ input suppliers/ Private Companies(commercial farms, seed companies) and other NGO's	Strengthening seed system and facilitation of seed low policies/ demand driven input supply/ mechanization of vegetable production (technology introduction, technology transfer, knowledge and skill).
7	Small scale farmer associations, primary cooperatives and unions	On farm technology evaluation, multiplication, adoption and dissemination, input supply and provide market information.
8	Ethiopian and Regional Seed Enterprises	Facilitate and multiply adequate quantity of improved seed for improved varieties
9	Agro-Processing Industries	Technology demand, development of value added products and provide technical support
10	National and Regional Soil Testing Laboratories	Provide advisory services and collaborate in soil related research.

Appendix Table 2 Institutional linkage or collaboration

No	Institutions	Contribution
1.	Ministry of Trade	Develop and implement policy issues facilitating production and marketing of vegetable crops for domestic and export
2.	Ministry of Industry	Facilitate expansion of agro-processing industries and strengthening linkage among different stakeholders (provide information for research for development of technologies for agro processing industries)
3.	Ethiopian Food, Beverage and Pharmaceuticals Development Institute	Provide training and advisory services, development and implementation of need based development strategies and policies and provide export market expertise.
4.	International Research Institutes (AVRDC, NRI, IPGRI, KOPIA, ACIAR, ICIPE, ASARECA, etc.)	Involve on collaborative project development and implementation, capacity building, provide germ plasm and information in recent scientific advancements.

Appendix Table 3.List of research processes/disciplines integrating in vegetable crops research

No.	Process	Areas of integration on complementation
1	Crop research	Generate technologies/varieties, IPM, information, crop management technologies.
2	Land and water resource research	Develop fertility and irrigation management technologies.
3	Biotechnology	Assist the breeding program and generate technologies/varieties, molecular information on different aspects
4	Agricultural economics, extension and gender research	Delivery of technologies/knowledge/information and popularization. Identification and prioritization of key (production constraints, postharvest, market and consumption), adoption and impact studies.
5	Agricultural mechanization and post-harvest management	Development of small scale farm implements, post harvest handling, storage and transportation technologies.
6	Biometrics, GIS and Agro-meteorology research	Identification and prediction of weather and climatic condition and avail information for research.
7	Quality Agricultural Research	Development of post-harvest techniques, nutrient profile and vegetable based value added products.

Enset Research Strategy

Introduction

In Ethiopia, agriculture is one of the sectors considered the most critical economic pillar and contributing over 41% of the regional GDPs and directly employing over 75% of the population. As a result, Agriculture contributes the highest share of the Gross Domestic Product and foreign currency earnings of the country from the sale of agricultural outputs abroad. Moreover, the sector creates employment opportunity to the majority of the country's population and at present 83 percent of the country's population depends on agriculture to sustain their livelihood. Hence, as it had been for centuries in the past, still being the leading sector at present, it is believed to remain being the determinant sector to play a dominant role to bring about an overall sustainable economic growth to the country, for the years to come.

Agriculture is characterized by subsistence mode of production with extremely low incomes and hand-to-mouth livelihoods of the smallholder growers. As a result the current agricultural development plan developed a strategy i.e. Agricultural Development-Led Industrialization (ADLI), focuses on the commercialization of smallholder agriculture through the production of those commodities that are competitive both at local and foreign markets. This will be materialize if and only if persistent efforts to increase productivity through increase use of farm inputs such as improved seed, fertilizers and modernize the farm activity through increase use of modern and improved farm implements and farming systems as well as through the introduction of modern farming technology to the sector as a whole will be implement by the government and the concerned stakeholders including the farmer.

Enset is grown in south-western part of the country and covers considerable land area within the private holdings (Figure 1). A total of 312,171.98 hectares of land was under enset in the country, taking up about 2.30% land area covered by all crops at country level. The number of enset trees to be harvested, in the current agricultural year, from all over the country is estimated to be 112,522,152. Thus, the total produce in the form of *amicho, kocho,* and *bulla* is 23,821,849.47 quintals, 28,329,103.94 quintals and 950,414.35 quintals respectively (Table 1). In this case, enset has a strategic importance in the agricultural sector based on its contribution to food security and import substitute.

Around late 1960s enset research was started in Debre Zeit Research Center where some varietal evaluation for yield and bacterial wilt were conducted. Since 1980 enset research activities at this Center was also discontinued. In 1972/73 enset clones were collected from different enset growing areas and established at Holetta Research Center. In 1976 this collection was taken to Wolaita Agricultural Development Unit (WADU). In WADU variety and agronomic trials were conducted, but in early 1980s enset research in WADU was discontinued. Development of enset processing devices was started at Nazreth Research Center in 1977. Some processing devices were developed and introduced to users. After elapse of sometime the activity is reinitiated recently.

In 1986 Areka Research Center has been established mainly for enset research and since then improvement and agronomy trials have been carried on. At the same time, trials have been started at Hawasa Research Center on enset pathology and entomology. Currently some enset research activities are being carried by some of the higher learning institutions. Currently, enset research programs are coordinated across federal and regional research centers by Areka Agricultural Research Center. Over the years, sensible achievements have been made with respect to the development of improved technologies involving varieties along with improved management practices, generation of information and promotion of improved technologies. These achievements had been well documented and major gaps were identified through two consecutive international enset workshops carried out in 1997.

The first comprehensive national enset research strategy was developed in 2000. However, it was not implemented as planned due mainly to structural changes in the research system. The Program has been tasked to develop an integrated and multi-disciplinary national enset research strategy plan for the next 15 years. This strategy aims to sustainably develop enset technologies by different disciplines to increase the productivity of women, men and youth smallholder enset farmers to improve their livelihood and incomes, while meeting overall goals of the Ethiopian Growth Transformation Plan (GTP II).

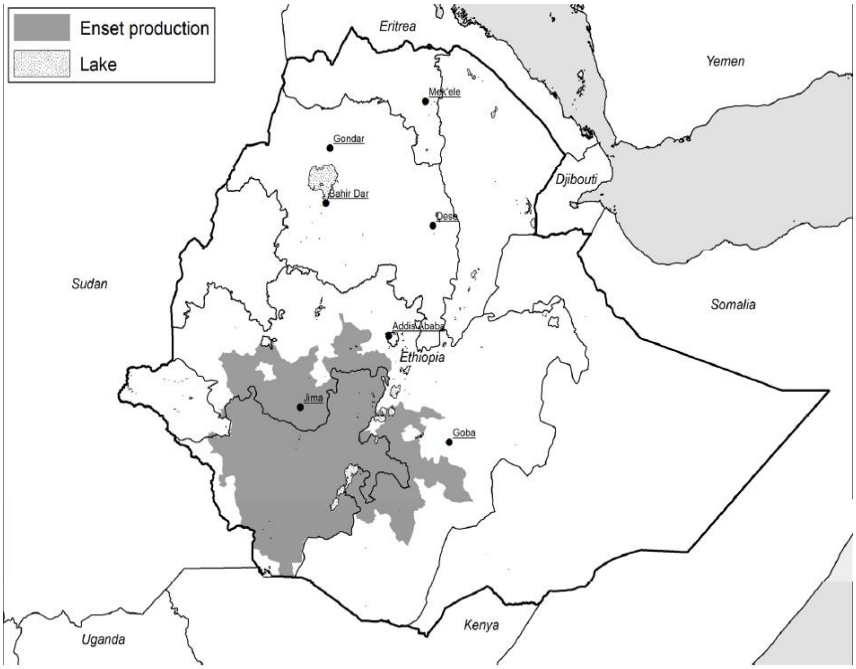

Figure 1.Geographical distribution of enset production in Ethiopia

Rationale for the Strategy

Ethiopia enters GTP-II, agricultural research in Ethiopia is found at the crossroads where urgent and quick action is needed to decide on an appropriate, effective, and sustainable national agricultural research system that would simultaneously be able to address the objective of poverty alleviation and food security on the one hand and increased competitiveness and profitability on the other.

Research in agriculture is an important, even core, element in the alleviation of poverty. Research leads towards higher levels of productivity and increasing incomes for both rural and growing urban populations. These improvements can lead to better health through better nutrition and improved local economies and services.

Therefore, investments in the rural sector must generate new knowledge through research and provide the enabling environment and market opportunities that allow research results to carry through to sustainable development outcomes.

Ethiopia need to develop the sector and increase the production and productivity; develop a national research strategy that needs to contribute to development, translating research results into development outcomes and need to be economic driver to reduce poverty and ensure food security. The lesson learned from this is that availability of production inputs, proper dissemination of proven technologies and full participation of stakeholders in the transfer process can bring significant success in enset production and productivity.

EARI rationale for developing a national enset research strategy is the belief that the crop will contribute to the food security and the economic development of enset producers and processors and the well-being of numerous disadvantaged communities and individuals in the country. All in the research program transforming itself to explore alternative options for effective coordination, resourcing, development and over-sight for the National Agricultural Research System (NARS). The strategy document will be used as a guideline and road map to direct research undertakings in developing reliable technologies that will increase enset production and productivity. This will help then contribute to achieve Ethiopia's long term vision of becoming a middle income economy.

Vision

To be a leading enset research commodity providing enset technologies, knowledge and information that enables the crop to leading food and export crop of the country.

Mission

To generate, develop and promote improved enset technologies for increasing enset productivity, policy for improving productivity, sustainable development and conserving the natural resources

Goal

The goal of enset research commodity is to enhance food security and income of enset farming communities by increasing the production and productivity of enset through efficient development of improved and sustainable technologies.

Objective

- To enhance agro-ecologically based enset production and productivity to maximize its contribution to food security and
- To strengthen market oriented/demand driven enset production and utilization through appropriate technologies that enhance income generation.

Importance of the Commodity

Agriculture

Agriculture is a major contributor to the national economy of Ethiopia, representing 41% of Ethiopia's GDP I. Enset-based farming system is one of a major agricultural system in Ethiopia that serves as a backbone for at least one-fifth of country's population. The significant feature of the enset subsector in Ethiopia has been briefly outlined as follows.

Agro-ecology and farming system

The enset agro-ecology ranges from 1200-3100 masl, but scattered plants can also be found at lower altitudes. However, it grows luxuriously in elevation between 2000 and 2750 masl. Enset is not tolerant to freezing and frost damage on upper leaves is commonly observed 2800 ma.sl and serious stunting is seen above 3000 ma.sl. Average rainfall of 1100-1500 mm per year and mean temperature of 16–20 ^{0}C is optimum for its growth. Enset grows well in most soil types provided they are sufficiently fertile and well drained. Generally, Enset is grown in more than seven out of 18 major agro-ecological zones (AEZs) in the country. Except the difference in area coverage in the respective agro-ecologies, enset is equally important in all the seven agro-ecological zones. The seven enset producing AEZs are:

Hot to warm sub-humid lowlands (SH 1)

SH1: Characterized by hot to warm lowlands and divided into 4 sub-zones. It covers 7.45% of the country. Areka and Woerabe research centers represent this AEZ.

Tepid to cool sub-humid mid highlands (SH 2)

SH2: Characterized by tepid to cool sub-humid mid highlands and It covers 7.6% of the country. Characterize this zone, and it is sub-divided into four sub-zones. Areka, Awassa Arbaminch and Jimma research centers represent this AEZ.

Cold to very cold sub-humid sub afro-alpine to Afro-alpine (SH3)

SH3: Characterized by cold to very cold sub-humid sub-afro-alpine to afro-alpine mountains. It covers about 0.47% of the country with one sub-zone of the country. It is served by Kulumsa and Sinana Research Centers.

Hot to warm humid lowlands (H1)

H1: Characterized by hot to warm humid lowlands and consists of three sub-zones. This zone is partly represented by Jimma Research Center

Tepid to cool humid high lands (H2)

H2: Characterized by tepid to cool humid mid highlands and consists of three sub-zones. The area includes southern part of Oromia and SNNPR. Different root and tuber crops and vegetable crops are successfully produced. It is represented by Bonga, Jima and Tepi research centers.

Tepid to cool moist mid highland (M2)

M2: Characterized by tepid to cool moist mid highlands and sub divided into five sub-zones. Ambo, Holetta, Kulumsa and Yabelo research centers represent this AEZ.

Cold to very cold sub-afro-alpine to Afro-alpine (M3)

M3: cold to very cold moist sub-afro-alpine to afro-alpine: It covers 0.64% of the country with one sub-zone. Ambo and Holetta research centers represent this AEZ.

Genetic Diversity

Basic botanical differences established between the two genera i.e. *Musa* and *Ensete* of the musaceae family. Ethiopia is one of the primary centers of origin and diversity for enset. Hence, the country harbors huge wealth of genetic diversity in the enset crop. Farmers' rich knowledge that is accumulated on the crop over many years has played a significant role in naming, characterization and maintenance of the existing genetic diversity. Enset producing farmers have their own folk naming and classification system to distinguish one landrace from the other. Sometimes it is difficult to understand and reclassify, even while watching them to characterize. The classification of enset landraces has been accommodated by phenotypic differences, unique traits and specific uses of landraces. These are common characteristics of folk classification systems in enset. Folk nomenclature is an integral part of the variety management in enset farming systems. In general, this study and the previous studies have shown that different ethnic groups in the enset farming system demonstrated the existence of considerable amount of indigenous ethno-botany knowledge. High landrace diversity in a region may indicate extended periods of enset cultivation and a more subsistence form of production.

Production and productivity

Enset-based farming system is one of a major agricultural system in Ethiopia that serves as a backbone for at least one-fifth of country's population. Enset has been selected as a

typical multipurpose crop of which every part is thoroughly used for food, feed, medicinal, construction and ornamental purposes. Throughout the growth stage the corm, pseudo stem and leaves are used for various purposes. Enset is intimately associated with the daily lives of the farmers. Owing to these facts, farmers indicated that, 'enset is everything for us'.

Over the last decades, the total area covered with enset crop has grown from 65,000 ha to about 300,000 ha. The Southern and Oromia region produce 80% of the crop.

The productivity of the crop is also very high compared to other crops but varies depending on edaphic factors, altitude, cultural practices and varietal differences. Actual fresh *kocho* yield of enset reported by CSA (1997) was 28.01 and 25.93 kg/plant in Oromia and SNNP regions. From these figures the national average actual '*kocho*' yield in tons ha^{-1} $year^{-1}$ was found out to be 11.87, assuming 2222 enset plant ha^{-1} and also reported the national average yield to be between 7.41 and 11.95 tons ha^{-1} $year^{-1}$ assuming 2000 plants ha^{-1} The average *kocho* yield of released enset varieties was 10 to 31 tons ha^{-1} $year^{-1}$(Table 2). CSA (2015) also reported that actual fresh yield of *kocho* yield of enset was 26 and 24 kg/plant and the national average to be between 11.5 tons/ha. Fresh yield potential of *'kocho'* may go up 150 $tonsha^{-1}year^{-1}$ assuming growth period of 3 years and plant population of 2500 enset plants ha^{-1} (calculated from total dry biomass which is 30% of the total fresh total biomass with harvest index of 0.5)

The amount of food attainable from 50-60 Enset plants per year could provide enough food for an average family of 5-6 persons. Enset products are available throughout the year as *kocho* and can be stored in pits for long periods of time without spoilage. These all shows how fast enset cultivation is expanding and farmers are getting more relied on the crop in the changing climate to satisfy their needs.

Table 1.Area, Production and Yield of Enset crop for Private Peasant Holdings for Meher Season 2015/16 Ethiopia

	Zone/ Region/National	Number of trees harvested	Production In Quintals		
			Amicho	*Kocho*	*Bulla*
	Ethiopia	112,522,152	23,821,849.47	28,329,103.94	950,414.35
A.	S.N.N.P.R	77,032,108	17,220,257.28	19,935,121.40	589,993.22
1	Gurage Zone	2,894,268	831,678.13	865,877.78	33,059.91
2	Hadiya Zone	2,703,039	590,662.03	622,029.31	60,567.01
3	Kembata T/ro Zone	1,463,828	17,404.11	24,984.73	947.96
4	Sidama Zone	39,092,279	9,834,586.49	9,422,838.03	294,456.75
5	Gedio Zone	7,776,231	3,003,975.22	3,421,855.40	61,909.36
6	Wolayta Zone	2,014,068	444,343.35	476,065.62	46,910.55
7	Sheka Zone	6,385,174	931,646.82	2,786,619.67	15,486.49
8	Kaffa Zone	6,263,281	35,642.69	152,250.85	3,126.45
9	Gamo Gofa Zone	2,977,505	45,511.31 *	78,975.41	5,423.93
10	Bench-Maji Zone	412,976	43,344.01	99,627.53	926.4
11	Yem Special Wereda	282,845	-	168,750.88	6,529.44
12	Dawro Zone	2,455,935	593,772.08	1,087,415.75	-
13	Konta Special Wereda	230,987	81,552.52	103,337.63	-
14	Siltie Zone	767,020	446,757.09	304,825.98	23,917.08
15	Segen Peopls's Zone	813,126	319,381.44	319,669.85	36,731.89
B.	**Oromia Region**	**35,263,883**	**6,601,592.20**	**8,393,982.54**	**360,421.13**
1	Jimma Zone	5,934,782	207,207.23	25,181.88	1,551,164.80
2	West Shewa Zone	861,516	265,786.74	380,214.29	14,415.55
3	Borena Zone	1,024,398	306,338.71	350,366.85	7,936.80
4	South-westShewa Zone	2,474,999	495,358.68	543,767.82	59,975.48
5	Guji Zone	5,495,623	1,318,146.01	1,440,028.85	75,167.76
6	West Arsi Zone	18,120,920	4,008,754.82	4,128,469.93	177,743.66

Source: Central Statistical Authority (2015/16). Area of production of major crops. Agricultural Sample survey 2015/16 (2008E.C.). Report on Land Utilization (private peasant holdings). Volume I. Statistical Bulletin 584.

Table 1.Average quantitative values of the six released varieties

Character	YANBULE	GEWADA	ENDALE	KELISA	ZERITA	MESENA
Pseudo stem height (m)	2.35	1.72	1.98	1.6	1.66	1.58
Pseudo stem circumference (m)	1.44	1.22	1.3	1.27	1.32	1.13
Leaf height (m)	4.9	4.1	4.33	3. 6	3.99	3.52
Leaf width (m)	1.1	0.9	0.88	0.84	0.85	0.84
Leaf number	12	11	11	11	12	11
Unsqueezed *Kocho* (t/h/y)	31.49	22.75	26.16	23.13	24.58	19.81
Squeezed *Kocho* (t/h/y)	21.12	15.13	17.47	15.39	16.39	13.12

Source: Mikias Yeshitla and Zerihun Yemataw (2012). Past Research Achievement and Existing Gaps on Enset (Ensete Ventricosum (Welw.) Cheesman) Breeding. In Mohammed, Y., Tariku, H., (eds.).

Food and Nutrition

Enset is one of the potential indigenous crops for food production can be grown everywhere in Ethiopia. The major foods obtained from Enset are *kocho, bulla* and *amicho*. The enset cultivation system is economically viable and is one of the few successful indigenous crops that have become sustainable in the agricultural systems. It is sustainable and has been providing foods for humans for generation from the same plot and maintains the quality of life of the people.

Nutrition content of enset

Enset plants produced much more energy per unit space and time compared to other high energy producing crops. The average energy production rate from enset was about 286 and 172% higher than that of cereals, root and tuber crops. The main future of enset foods is their high energy value (1410-1950k) per 100 g dry matter of *kocho* and (1580-1850k) per 100g dry matter of *bulla,* derived almost entirely from carbohydrate. Fresh *kocho* contains 47-62 % moisture per 100g fresh weight. The approximate composition of *kocho* per 100 g dry matter is: 1.1-2.8g protein, 95-98g carbohydrate, 0.2-0.5g fat, 2.3-6.2g fiber, 1.7g ash, 60mg calcium, 68mg phosphorus, 7mg iron, 0.06mg thiamine, 0.08mg riboflavin, and 0.6mg niacin. The moisture content of *bulla* ranges from 44-55 g per 100g fresh material. The approximate composition of *bulla* per 100 g dry matter is: 0.4-0.8g protein, 93-98g carbohydrate, 0.2-0.4g fat, 0.6-0.8g fiber, 0.2g ash, 91mg calcium, 44mg phosphorus, 5.8mg iron, 0.06mg thiamine, 0.04mg riboflavin, and 0.2mg niacin.

Economy

Agriculture and allied activities had been and will continue to play a significant role in the Economic life of Ethiopia in various aspects. The first contribution that agriculture makes in economic well-being of the nation is to the supply of food. Eighty Five percent (85%) of the national population is engaged in agricultural activities providing food to themselves and the rest of the population. Enset is the most widely used staple food crop for millions of people living in South and Southwestern Ethiopia. It plays a central role in

the economic life of the South and Southwestern people, who rely on it. It gives a higher and more dependable yield than any other known crop.

Domestic Consumption

Enset is a multipurpose crop which is utilized for human food, animal feed, medicinal or ornamental uses. Farmers indicate that Enset is their food, their cloth, their house, their bed, their cattle feed and their plate. It has high significance in day to day life of the peasant households cultivating this crop as staple food. A large household can be supported by enset grown on a limited area of land. It has been articulated that the amount of food obtained from 50-60 enset plants per year could be enough for an average family of 5-6 persons. Enset guarantees food security and stability to the household economy in that the processed produce can be stored for a long time. In addition, the live plant can be maintained on farm and harvested any time when the need arises. It can be harvested and consumed before it is matured and these qualities of the crop have in part contributed to the fact that enset areas are not characterized by a history of famine. The last five years (2010-2015) CSA report indicated that the produce from enset has increased by three-fold from 694,810 to 2,724,214 tons of *kocho* in 2010 and 2015, respectively (Annex 1). These all shows how fast enset cultivation is expanding and farmers are getting more relied on the crop in the changing climate to satisfy their needs. The market demand for enset nowadays is increasing as the consumption of *kocho* and *bulla* has widely expanded to even big cities such as Addis Ababa. According to the local people in enset areas, they are increasing their production as the demand and price for the products are rising, despite the increase.

Enset fiber is the by-product of Enset that is left after decorticating the leaf sheathes. Enset fiber is used for making bags, ropes, twines, cordage, and mats. Its strength is found to be equivalent to the important fiber crop, *Musa textiles* (abaca) and serve as a valuable raw material in local industries. Some Enset clones are known by farmers to have medicinal value for both humans and animals. These clones are claimed to heal bone fractures, are used for treatment of diarrhea and delivery problems i.e. assisting to discharge the placenta. The fresh and dried leaves of Enset have various uses. They are used as food wrappers, serving plates and pit liners during *kocho* storage. Dried petioles and midribs are used as fire wood, to make mats and as tying materials. In the dry season, the fresh leaves are used as cattle feeds. It therefore contributes enormously to food availability and economic sustainability.

Supply of raw material for local agro-industries

Enset is processed to produce both edible and non-edible products. *Kocho, bulla amicho* are products used for human consumption while the byproduct such as fiber remaining after kocho and bulla extraction are an excellent source for fiber and starch industry. The edible components bulla used as starch for textile, paper and adhesive industries and many other industrial products. Moreover it can be used as alternative starch in pharmaceutical industries. The crop also produces high quality fiber comparable to Abaca

fiber; world class fiber, which is used for variously purposes depending on the social and cultural facets of communities. Even though, more than 600tons of enset fiber supplied per year to local factories it covers only 30% of the demand (Brandt SA, Spring A, Hiesch C, McCabe ST. Ethiopia has great potential to make use of enset fiber to develop products such as food grain carry bags, starches for textile, chemical and food industrial sectors and garment making .The utilization of enset in various products development save the foreign currency and also helps to increase the export potential of Ethiopia by using AGOA and COMESA export opportunities. Thus, enset products such as starch and fiber potentially supplement as raw material requirement of agro-processing industries augmenting foreign currency balance of the country.

Socio-cultural significance of enset

Socially, people in the south and Southwestern parts of the country not only depend on enset for food and cash, but also consider it as part of their cultural heritage. They have a strong attachment to the crop. Many farming households grow enset for economic as well as non-economic purposes. According to Murdock (1959), a system of social, economic and ritual practices has developed around the cultivation of enset. The Gurage people, for example, use it for purposes such as medicine, compensation payment, and ritual offerings. Among the Gamo highlands, rituals associated with birth involve the use of a particular clone of enset.

Environmental sustainability

Besides food and fiber products, enset plays a very important environmental role. It protects the soil from erosion and runoff, it serves as shade and improves the microclimate for the undergrowth, and the litter from the leaves and other parts improve soil fertility. Unlike annual plants, a small portion of the biomass is taken out of the system during harvest, while the largest portion is returned directly as litter or indirectly through the manure. In general, enset has ideal attributes for low-input sustainable agricultural production systems: It is high yielding; it can be harvested any time once it is about four years old, it doesn't require external inputs, it protects and/or enhances the environment, and it has multiple functions. It is, therefore, no wonder that it has been supporting a very dense population for a long time. Because of its contribution to food security and environmental resilience, enset has received attention from researchers and development workers over the last few years.

Enset can be inter-cropped with many other crops (e.g. coffee, taro, vegetables, and yam) that need canopy, while there is no demonstrable competition effect on nutrient utilization. It provides a favorable microclimate as a shade tree when used in intercropping with coffee.

Enset contributes for higher reduction of losses of plant nutrients particularly nitrogen loss through leaching as compared to annual crops and it is a sustainable system with regard to maintaining the soil fertility. Soil fertility is maintained and even increased

around the garden area of Enset and taro fields. Enset is a manure loving plant and hence it integrates well with livestock production.

Assessment of External and Internal Environments

Assessment of External Environments

General external situation/environments (PEST+)

Under the general external situation, analysis was made on opportunities and challenges that based on political, economic, socio-cultural, technological/technical, and environmental (PEST +) dimensions. Systematic analysis of these factors would help to have better understanding on the big picture of external factors affecting either positively or negatively and thus to craft the strategy so that it would make best use of the opportunities created by the positive influences and conversely to be cautious about the negative influences they pose or systematically address the challenges to overcome their obstruction.

Political dimension: Assessments with the political points of view were made whether the strategy is line up with the national, sectoral and institutional policy, strategy and regulatory/legal frameworks and priorities. Since the adoption of the Agricultural Development Led Industrialization (ADLI) by the government of Ethiopia, all the policy and strategy frameworks and development programs recognized agriculture to be the engine of Ethiopia's economic growth and development. Again, food and nutrition security and climate resilient is one of the government policy and gives priorities to crops with these potentials. Moreover, the current GTP II which provides even greater emphasis to industrialization places greatest priority to those agricultural sub-sectors fostering supply of raw materials for the growing agro-industries and import substitution. Enset crop has unexploited potential to contribute towards food and nutrition security, climate resilience and industrial input substitution. Therefore, so many opportunities are set forth by the policy environment to promote research and development of the enset crop. As conducive the policy and legal frameworks put in place, there are also a number of challenges that may surface in due course.

Economic dimension: the great demand for food & nutrition security to continuously growing population and the need for industrial import substitution in line with its high yielding and multiple purposes potential create the opportunity for the enset crop to thrive. Such an increase in the demand side will be the motivation for both the farmers and processing industries to increase their outputs. The research has to; therefore, keep pace with the need of the farmers to increase production mainly through increasing productivity and minimizing pre and postharvest losses; while at the same time meeting the demand for food and nutrition security and raw materials for the industries to fulfill their requirements in quantity and standard quality.

With the nature of its wide genetic diversity, various agro-ecologies adaptability, new potential areas to grow, high productivity and good nutritional compositions; enset will support the country to fulfill food and nutrition security and import substitution demand. Enset has even more the potential to be export commodity. Currently, more than 20 millions of people in the country use it as staple food crop. It is also used as animal as feed at dry weather condition and industries like "*meher kacha*" used its fiber as input for the production of strings and sacks. Also there are some factories that extract starch from enset *bulla* that used as input for different industries. The existing economic opportunities, however, are not without posing some challenges that the research team needs to be cautious about or address during the coming years.

Socio-cultural dimension: Ethiopian farmers; especially south and south western parts of the country, have long culture of growing enset crop. Ethiopia is the only country that uses enset as food crop in the world. Therefore, like the other indigenous crops, it is the identity crop of the country. In most case enset is cultivated around homestead and considered as a grace for their residence that increases the aesthetic value of the environment. Beyond food sources enset is used as an indicator of wealth status and working strength of the farmers in the community and its farming communities used enset as a potential source of feed for their animals, constructing materials, medicinal, ornamental crop. However, the above mentioned opportunities to enset production sustainability, there are socio-cultural challenges; like attitude of none enset production society on enset production and products together with lack of harvest and post-harvest mechanization, that limit the expansion of its production in to new areas. It is thus essential for the research team together with its key stakeholders to unravel the opportunities that it can make use of and challenges that it has to face up in order to address or change the perception of the farming society that growing enset should be considered and handled as such to be economically, socially, environmentally profitable, viable and sustainable venture.

Technological dimension: Outstandingly peculiar feature of enset is the fact that right after production the produce has to be for utilization as food. However large amount of enset fiber product is used at house hold level for making rope and different furniture's; like mats, bags, it is taken to factories for the production of strings, sacks. The industrial sector processing fiber in Ethiopia has used enset fiber as input. What has not changed much is the rate at which the domestic supply of fiber is much less than the demand of the factory.

Environmental dimension: Enset has wide range of bio-diversity and ability to adapt wide range of agro-ecology. It has also considerable carbon absorption nature that contributes towards climate resilience. While the country is a natural home for enset crop it is also the locus of genetic diversity for others. Such a diversity of ecological factors and crop types, on the other hand, provides a fertile ground for range biotic agents such pathogens, insect pests, weeds and other menaces to co-evolve with and survive on the crops against the interest of man. The damages from these biotic factors coupled with

climatic and edaphic factors hindering normal growth and potential of the crops are among the primary issues that the research team would target to address. It is therefore, rational to distinguish what opportunities these environmental factors could offer in order to take advantage of them while at the same time to be prepared to tackle the challenges they may incur.

Stakeholder analysis /Operational External Environment

The need for innovative research in enset production system has been highlighted by range of stakeholders. Assessment of potential stakeholders has paramount importance for joint planning and collaboration for successful implementation of envisioned milestone of the sector. The key stakeholders with their role and responsibilities are briefed as follows (Table 3).

Table: 3.Lists of stakeholders with their roles.

Stakeholders	Roles
Ministry of Agriculture	• Provision of logistic support • Capacity building (infrastructure, training, laboratory facilities, …) • Community mobilization, enhancing overall facilitation
The Ethiopia Agricultural Research Institute (EARI)	• Allocation of resources • Capacity building (infrastructure, training, laboratory facilities, …) • Research program facilitation, organizing of multi-stakeholders platforms • Monitoring and evaluation of research program
Southern Agricultural Research Institute (SARI)	• Coordinating research on national enset research project • Allocation of resources • Capacity building (infrastructure, training, laboratory facilities, …) • Research project facilitation • Organize multi-stakeholders platforms • Monitoring and evaluation
Areka Agricultural Research Center (Center of excellence)	• Coordinating research on national enset research project • Conduct enset research • Research project facilitation • Establish and organize multi-stakeholders platforms • Facilitate cooperation among collaborating institutions • Joint research • Germplasm maintenance and exchange • Technology promotion • Monitoring and evaluation
Kulumsa, Jimma, Holleta, Bonga, Awassa, Tepi, Ambo, Worabe Agricultural Research Center (Core Collaborating Center)	• Conduct enset research • Joint research • Facilitate cooperation among collaborating institutions • Germplasm maintenance and exchange • Technology promotion
Regional agricultural research Institutes (RARIs)	• Strong collaboration • Allocation of resources • Capacity building (infrastructure, training, laboratory facilities, …) • Facilitate and implement regional research programs

	• Organizing of multi-stakeholders platforms • Monitoring and evaluation of research program
Universities	• Training (Short and long term) • Cooperation and implement research projects • Monitoring and evaluation
Ethiopian Biodiversity Institute	• Provision of financial support • Collaboration and implement research projects • Monitoring and evaluation
Commission of Science and Technology	• Provision of financial support • Collaboration in research projects • Monitoring and evaluation
Agricultural Transformation Agency (ATA)	• Technical support • Collaborating for research
CGIAR centers and External collaborator Universities (Exeter, Leister)	• Provision of Technical and financial support • Capacity building (infrastructure, training, laboratory facilities, …) • Collaboration and implement research projects
Rural technology Centers	• Training (Short term) • Collaboration and implement research projects; like for improved farm implementing equipment
NGOs	• Provision of financial support • Collaboration in research projects • Capacity building (infrastructure, training, laboratory facilities, …) • Scaling out of improved technologies
Privet sectors	• Cooperation in research project • Active engagement enset product • Technology multiplication
Mass Medias	• information dissemination and community sensitization
Farmers (Community based organization)	• Full participation in research project planning and implementation • Engage community mobilization activities • Organizing farmers groups,

Benchmarking

As pointed out earlier, Ethiopia home land and has a considerable potential for growing enset not only in terms of suitability of the existing ecological settings but also a number of other factors discussed in the preceding sections including favorable policy, economic, socio-cultural, technological and environmental circumstances. As part of the external environmental factors, it is also a strong exercise to examine the potentials of the crops which can and should be exploited by drawing lessons from existing indigenous knowledge and other countries that have advanced levels of research achievements on related crops; like abaca for fiber production. As enset is indigenous crop, existing indigenous knowledge and the results of previous research works are considered as bench mark.

In addition, countries like Uganda are given us good lesson to enst bacterial wilt management; as they achieved incredible result on bacterial wilt management on their staple food crop; banana.

For Fiber south east Asians like Philippines and Indonesia that they have good achievements on producing and exporting abaca fiber to the world market.

For starch production; the experience of starch privet company that extract enset starch in our country and Germany, Netherlands, Poland that produce starch from potato are our bench marks.

Assessment of Internal Environments Strategic Issues Facing the Commodity

Assessment of internal environments is an introversive process whereby the research team examines the capacity that exists within the EARI system and can readily be utilized by the team to deliver outputs. Such a capacity that is readily available for the team denotes the strength of the team while the capacity which is required to deliver the outputs but falls short to exist symbolizes the weakness of the team. Assessment of the internal environment is thus about precise identification and articulation of strengths and weakness of the research program. Capacity in this context encompasses a wide array of topics including institutional capacity which signifies the available or lacking human, physical and financial resources; technical or technological capacity and organizational capacity which deals with the questions of functional integrations within and between disciplines to forge complementarities and synergies. Below are briefly discussed the elements of internal environments examined to synthesize summaries of the Strengths and Weakness provided in Table 4.

Resources

The human, physical and financial resources have an influential power on program implementation, coordination and administration. Therefore, the level of human resources capacity, financial capacity and the physical resources available and lacking were assessed and tabulated as strengths or weaknesses.

Inter- and intra- disciplinary integrations, complementarities and synergies

The success of enset research depends on integrated and combined efforts of various research disciplines and sectors. In addition to that of the mainstream disciplines; breeding, agronomy, crop protection, socioeconomics & extension and food science, there are clear possibilities of realizing complementarities and synergies by working together with experts of other fields. Important among these potentially potent areas of integration include: Agricultural-Biotechnology Research, Agricultural and Nutritional Research Laboratory, Land and Water Resources Management Research, Enset-processing and mechanization, Technology Multiplication and Seed Research, Climate and Geospatial, Livestock Research and ICT. Assessments were thus made whether or not there could be integrated for synergies with these compelling areas of research.

Technologies

As has been said earlier, a concerted research on enset started before three decade's and to date 6 improved varieties were released (see Table 2). Suitable agronomic recommendations were established. The major diseases and insect pests of the crop were identified and their management measures were worked out and established. Whether or not the changes brought about by these technologies are in balance with the expectations are evaluated to point out and build on the strengths and draw lessons from the weaknesses.

Organization, implementation and geographic coverage

Lack of strong systems and procedures (i.e., organizational capacity) at different levels is an area of capacity impairment that affects effectiveness. Limited intra- and inter-institutional linkages are also sources of limitation for rapid progress. Organizational strengths and weaknesses that would correspondingly make the growth of enset research to take upward or downward trend were analyzed from the center-level, institutional level and national level perspectives.

Strengths, Weaknesses, Opportunities and Challenges by the Research Themes

Table 2. Summary of analyses of external and internal environments reflected in terms of strengths, weaknesses, opportunities and challenges pertaining to the different thematic research areas

Thematic area	Strength	Weaknesses	Opportunity	Challenge
General	• Sufficient working premises (offices and experimental fields at center level); • There is a core research team representing the different disciplines at the coordination center; • Recognizing enset as a national commodity will draw emphasis and attentions of decision makers; • The culture of research collaborations to conduct joint reviews and planning, multi- location trials, adaptation trials etc. among research centers.	• Lack of skilled human power especially in modern tools of crop improvement, protection, post-harvest and quality analysis; • Limited staff time for disciplines other than breeding and agronomy; • Turnover of experienced researchers; • Lack of standards or protocols for utilization of quality lab facilities (GC, NIRS.,; • Lack of self-contained lab, green house and standard store and • Poor linkage of the research with other stakeholders along the value chain.	• National focus on transformation of the agricultural sector through diversification and market-led production of high-value crops; • Encouraging Government policy for the establishment and expansion of agro-industries demanding raw material with high standard quality and the potential of the crop to provide industrial raw materials with competent quality; • High yielding ability, wide adaptability, and multi-purpose nature of the crop; • A large volume of fiber and starch have being imported annually and thus there is a huge potential for import substitution; and also import substitution is high GoE's priority; • High potential market for enset products in the country and • There are many institutions like universities which have the capacity to undertake basic and applied researches.	• Limited adaptation by non enset farming community. • Lack of market linkage • Lack of harvesting technology

Breeding and genetics	• Presence of relatively experienced breeders at the coordination and other center	• Limited support from CGIAR centers and lack of modern breeding laboratory and green houses.	• The country is center of origin and diversity for enset	• Enset genetic erosion due to EBW, competition from other crops and climate change
	• Availability of biotechnological laboratories at institute and SARI level	• Limited basic research on enset exists to serve as a basis for further exploration	• Diverse enset agro-ecology and farming system	• Shortage of field and laboratory supplies and consumables
	• Availability of field for screening of diseases of enset	• Limited applied research in enset improvement	• There is collection of germplasm material at the Ethiopian Biodiversity Institute (EBI)	• Inadequate facility and frequent training for laboratory technicians
	• Maintenance of more than 500 farmers variety and production of breeder seedlings	• Released varieties do not adequately address different use value and adaptation to various agro-ecologies.	• Availability of strong collaboration in training with international research centers	• Lack of laboratory consumables for quality analysis
	• Recent emphasis in multi-disciplinary research approach by the national and regional institutes (EARI); • Availability of varieties for kocho yield and quality; • Increasing focus on pharmaceutical and industrial uses of enset and • Presence of national and regional biotechnology laboratory and some trained manpower.	• Lack of genetic information (e.g. gene actions and inheritance of traits) to base on and plan genetic gains to be attained in order to improve disease resistance; • Use conventional method for variety development is so lengthy (it needs 7-10 years for variety release); • Lack of capacity in bioinformatics, genotyping, sequencing and their utilization in molecular breeding and • Limited focus on enset nutritional, pharmaceutical and industrial quality.	• Availability of diverse enset genetic resources (within & without); • Availability of decentralized research on enset by regional, federal and higher learning institutes; • Availability of modern biotechnological tools and facilities elsewhere to adopt, adapt and use and • Reproductive nature of the crop (Asexual and sexually propagated).	• Shortage of land and facilities for seedling multiplication; • Limited manpower in biotechnology at commodity base; • Difficulty for introduction of other Ensete species and • Insufficient genetic resource collection and management.

Breeding and genetics	• Increasing focus on enset production in marginal environments (low moisture areas)	• Breeder seedling insufficient quantity; • Limited technologies for low input management and marginal environments; • No variety released based on their animals feed quality and • Variety development programs are weakly linked with other research multidiscipline.	• Presence of policies and regulations on germplasm exchange, introduction of foreign plant material and plant quarantine; • Encouraging policy and Public investment for introduction and adaptation.	• Lack of capacity to identify resistance genes, mechanism of resistance and incorporate it in developing new varieties.
Agronomy and crop physiology	• Recent emphasis in multi-disciplinary research approach by the national and regional institutes (EARI) ; • Presence of relatively experienced agronomist at the coordination and other center; • Experiences in cropping systems research with legumes and other horticultural crops from which lessons could be drawn exist and • There are research centers with many years of experience in dry land agriculture.	• Blanket recommendations and coverage of only pocket areas; • Limited capacity to employ precision agriculture; • Limited focus on system productivity (enset-soil-livestock interaction); • No agronomic packages for low moisture areas; • Lack of integrated agronomic packages for all enset growing agro-ecologies; • Limited focus on physiological research and • Lack of training and experience sharing programs in crop physiology.	• Enset has long well established farming system;. • The culture of producing enset with integration with other crops and animals; • The existence of diverse agro-ecology suitable for growing enset are being cultivated by more than 20 million small farmers in Ethiopia; • Availability of compatible crops with enset in the production systems and • Government policy and focus on full package for increased productivity and production to realize food security.	• Climate change and natural resource degradation (Drought and heat stress); • Complex physiology of perennial crops in response to varied agronomic practices (eg. leaf removal) and production systems and growing AEZs; • Proper placement of resources to pursue market-oriented production while promoting some cropping systems like mixed cropping, etc. needs careful balancing and • Less focus on human power development programs in the area of crop physiology.

Agronomy and crop physiology		• Limited utilization of crop modeling tools and less focus on training in modeling; • The agronomic recommendations available may not suit for different agro-ecologies and farming system.	• Availability of physiological facilities elsewhere for application to incorporate physiological traits used for enset improvement program; • Wide availability and applicability of crop modeling tools to predict future crop production scenarios and • Presence of full time and working agronomist in the coordinating and other centers.	• Lack of equipment's and training programs in physiological research; • Inherent tradition in different agronomic practices; • There is lack of technical knowledge from the side of extension service providers (Wereda experts, DAs and SMS) on enset production
Soil and Water Management	• Attention given to organic agriculture (manure, compost, vermicompost); • Use of soil map based recommendation; • There exist strong soil and water management research facilities including well experienced personnel and equipped laboratories; • The research team has the experience of preparing packages of optimum soil fertility management options (fertilizer rates, mode and method of application) and • Availability of inorganic and organic fertilizer rate recommendation.	• Limitation in determining appropriate rate of organic fertilizers (compost, vermicompost, manures etc); • Limited recommendation for problematic soils; • Lack of recommendations on enset with other crop, animals and soil fertility management; integrated production system; • Recommendations on integrated soil fertility management appropriate for growing enset in different agro-ecologies are not available and • The soil fertility management recommendations are by and large general not tailored to specific agro-ecologies and farming systems.	• Availability of organic and inorganic fertilizer sources; • Attention given to micro nutrient fertilizers; • Presence of full time and working expertise in the coordinating and other centers; • There have now been established fertilizer blending plants producing and distributing fertilizers of various mixes including both macro and micro elements.	• The culture of not using inorganic fertilizer for growing enset; • High requirement for investment in soil sampling and analysis; • Lack of short term training programs or Technical Assistance for soil sample collection and analysis.
Crop protection	• Attention given to periodical survey and surveillance of major enset diseases and	• Lack of modern protection research facilities and highly trained technical staff;	• Existence of wide range of diverse wild enset out of the country; • Encouraging policy on protection;	• Climate change and variability leading to disease dynamics, insect pest epidemics and and

	insect pests; • Availability of relatively better wilt tolerant varieties against EBW; • Few studies on botanicals; • Availability of core team members of crop protection at coordination & collaborative centers; • Availability of relatively better basic knowledge on major disease and insect pest biology, and diversity; • Existence of recommended effective integrated cultural practices that enable to manage enset (EBW); • Surveys conducted in some enset growing areas; • Efforts made to develop varieties with resistance to major disease (EBW); • The existence of a research center working on crop protection including weed sciences can provide back up and • Economically important disease and insect pest of enset were identified.	• Limited focus on monitoring and pathogen evolution; • Limited promotion and adaptation of this recommended disease management practices by farming community; • Less attention given to occasional disease and insect pest survey in enset producing areas; • Less focus on identification of resistance genes of disease and insect pest and using for variety development; • Limited expertise for bio-control of diseases and insects; • Less frequent surveys for weed flora density and abundance and • Limited knowledge on diseases and insect pests identification, their biology and epidemiology.	• Existence of established government agricultural organizations up to *kebele* level and; • Regional and federal government give attention for community mobilization; • Availability of crop protection researchers in the coordinating and collaborating centers and existence of plant health clinics at region level; • Molecular laboratory and partner institution working on diversity and the information on related crops (eg. Banana); • Availability of enset landraces which confer genes for resistance against diseases; • Availability of molecular tools and modern approaches elsewhere; • Diverse agro-ecology suitable for enset production and • Available options for insect management (cultural, chemical, biological).	favors emergence of new enset diseases and insect pests; • Susceptibility of enset varieties to major enset disease (EBW); • Lack of complete resistant clone for enset bacterial wilt ; • Resistance of farmers to implement recommended cultural and sanitary control measures for EBW; management • Ineffective quarantine/regulatory system and surveillance and • Knowledge and skill gap on major enset diseases and insect pest biology and epidemiology and lack of strong and well equipped protection laboratory.

GIS and agro-meteorology	• Preliminary works for enset disease map	• Lack of crop suitability map, seasonal forecast and geospatial analysis information for production and marketing of enset crops	• Diverse agro-ecology for production of different types of enset for high yield, nutritional and and other use value	• Global climatic change affecting the suitable agro-ecologies turning them into non-suitable
	• GIS and agro meteorology research units are established in most research centers		• Sophisticated GIS and agro-meteorology technologies are available worldwide	• Big technological and research capacity gap and the technologies are expensive
Technology multiplication and seed research	• Established community seed production schemes for fast multiplication and outreach; • Availability of seed research discipline; • Six enset varieties have been developed and released along with suitable agronomic; recommendations • Closeness of the coordination center to the major enset production areas of makes to easily evaluate merits and the need for new technologies and • Conventional propagation and tissue culture protocols are developed for enset.	• Less focus on pre-basic seedling multiplication in required quantity; • Limitation in technical support to community producers in quality seed production; • Limited focus on enset seedling health and quality; • Less focus and lack of awareness on diseases and pests and • Lack of micro-propagation techniques and protocols for enset planting material multiplication.	• Strong demand from stakeholders for improved seedling for new areas; • Availability of privet planting material producers in the country and • Encouraging policy and public investment on technology multiplication.	• Shortage of land and appropriate facility for early generation seedling production; • Limited facility and expertise in seed quality research.
Agricultural Economics, Extension and Gender	• At the coordination center core research team representing the different disciplines that has been established also includes researchers of socio-economics, research extension	• Limited demonstrations and popularization of enset technologies; • Limited information on the production, marketing, processing and value chains on costs of	• Variety of enset production and utilization cultures regarding preparations of variety of traditional dishes and medicine; • Use of enset products for multiple purposes in multiple ethnic groups.	• Low rate of adoption of technologies and limited use of full packages by resource poor farmers • Weakness and lack of commitment of stakeholders

	and gender;	production and efficiency and cost-benefit analysis in major producing areas. .		platform (ADPLAC)
Agricultural Economics, Extension and Gender	• Closeness of the coordination center to the major enset production areas of makes to easily evaluate merits and the need for new technologies; • EARI has adopted the policy of gender as one of the crosscutting themes to be mainstreamed in all its implementation agenda; • Availability of research extension discipline; • Strong linkage and collaboration with farmers and extension offices to collaboratively organize farmers trainings, field days and travelling workshops; • Few value chain and map studied; • Increasing attention to gender and youth in research and • Few Studies and characterization of enset based farming systems.	• Lack of communication media in local languages (fliers, extension bulletins, leaflets, production manuals and mass media); • Limited farming system characterization in some enset agro-ecologies; • Limited market promotion has been done on enset fiber even with its competent quality with abaca fiber; • Level of technology adoption and determinants for adoption of enset is not clearly known at the national level; • Lack of participatory variety selection and inclusion of farmers criteria in variety development; • Less focus and mainstreaming of gender and youth in research interventions; • Limited involvement of all concerned stakeholders in collaboratively organized field days, travel workshops and discussion forum and • Limited information on international market of fiber and starch.	• The existence of high demand for Natural fiber; • Presence of Enset fiber demanding factory; • Positive tendency for enset production as food crop by community that were not previously familiar with its production; • High productivity, wide adaptability and climate resilient nature of the crop; • Different farming system and agro-ecology; • Presence of government structures at different levels (federal, regional, zonal, district and kebele levels) and other stakeholders to support the dissemination of enset technologies; • Presence of collaborative research and development planning platform (ADPLAC); • Availability of innovative and champion (model) farmer and • Availability of many actors (governmental, NGOs, agro-industries etic) in enset sector.	• Dynamism of enset production system (area shrink due to competition from other crops and climate change); • Lack of commitment from all value chain actors to hold together the chain; • Limited number and capacity of starch and fiber factories and • Limited Knowledge of farmers on quality fiber, bulla extraction.

Agricultural Mechanization	• Some efforts has been made by rural technology centers and polytechnic colleges to made enset farm implements • Availability of mechanization research	• Lack of recommendations on appropriate pre- and post-harvest handling practices	• Agricultural mechanization has nationally gained momentum as an essential element of the GTP • Mechanization services	• Advanced and expensive agricultural equipment in enset value chain makes the technologies unaffordable by small holder growers
Agricultural Mechanization	• EIAR has a solid experience in agricultural mechanizations and plenty of prototypes of farm implements suitable for small-scale agriculture	• Limitation on multiplication of prototypes of improved processing implements	• Presence of enterprises and farm machinery suppliers engaged in providing	
Agricultural Quality and Nutrition Research Laboratory	• Some studies on macro and micronutrient composition of enset varieties; • There is a relatively well equipped central quality laboratory at HQ and • Presence of food science and post-harvest researcher in core team at coordinating center.	• Limited information on post-harvest handling techniques and food process; • Limited information on indigenous knowledge on making variety food staffs prepared form enset at different culture; • Limited research on nutritional qualities of released varieties; • Little is known of inherent macro and micronutrient content of released enset varieties and local landraces and • Less focus on macro and micronutrient fortification.	• Rich Indigenous knowledge on making Variety food staffs prepared form enset at different culture and on post- harvest handling; • Multiple uses of enset and increasing demand for enset food products; • Favorable policy incentives for agro-processing industries for export market and • Increased local demand for processed enset products.	• Malnutrition and health defects related to un-balanced diet from consumption of few dishes; • Lack of investment in sector specific infrastructures and logistics.
Capacity building	• Efforts to retain the experienced senior staff for mentorship; Focus on modernizing the research producers by using modern farm tools (Processing	• Lack of joint review among different research disciplines; • Inadequate integration and cooperation of researchers and • Inefficient utilization of the allocated budget for running the	• Availability of young researchers in the research system • Government and donors support to capacity development	• Lack of conducive working environment in the research system; • Continuous turnover of experienced research staff; • Limited frequent training (long-

	devices.	enset research, and procurement of the facilities.		term and skill) to develop the skill and knowledge of research staff and • Inefficient budget release procurement system for utilizing the available resources.
Capacity building	• Project development for funding by donors	• Limited mentorship	• Presence of research facilities (national biotechnology laboratory, nutrition laboratory) and service given by different institutions	• Limited facility in enset planting material production; • Lack of greenhouses; • Limited laboratory equipment for physical and chemical analysis, physiological, pathological and quality tests; • Shortage of offices and laboratories and • Shortage of vehicle.
Cross cutting themes	• EIAR has a strong capacity to undertake ICT-based information compilation, dissemination, knowledge management and networking to promote the enset sub-sector and • EIAR has adopted the policy of climate change as one of the crosscutting themes to be mainstreamed in all its implementation agenda.	• Lack of a central data/information base that could be accessed through the network on what facilities a given center, research program or team is equipped with, what technical support the facility could provide for fellow researchers from other centers; • Weak linkages and inadequate scientific for such as ICT-based networking, regular discussions on specific research topics, projects and technologies Climate change (this is especially important in marginal areas where	• Recognizing the role Information and Communication Technology (ICT) can play in development, the GoE adopted the ICT policy and strategy; a significant progress was made in communications network in the country since the enactment of the policy and • The MoANR has since long ago adopted strategies and programs such as SLM that are being implemented nationwide.	• Impacts of climate change are associated with changes in the frequency, intensity, and predictability of rainfall and water availability with consequential effect of decreased agricultural production and food shortages and • Technologies enhancing adaptation and mitigation such as cropping systems etc. are merger.

		drought is an imminent problem. Also is becoming a threat the emergence of new pests or dynamic shift of those never been major pest earlier); • Lack of information and technologies and • Specifically tailored to address climate challenge.		

Strategic Issues Facing the Enset Commodity

Table 3.Strategic Issues (Gap Analysis) Facing the enset Commodity

Thematic areas/ research disciplines	Strategic issues
Breeding and genetics	• Limited basic research knowledge • Limited germplasm collection, conservation and characterization • Limited variety screening and development for diverse agro-ecology and uses • Narrow genetic resources base especially for specific traits (EBW resistance) • Limited application of Biotechnology tools for variety development and maintenance • Insufficient availability of breeder seedling
Agronomy and physiology	• Less information on enset cropping systems • Limited agronomic practices and techniques for different cropping systems and agro ecologies • Limited study on crop modeling • Inadequate information on crop physiology • Limited study on system intensification
Soil and water management	• Inadequate study on integrated soil fertility management • Limited study on soil fertility management for different soil types and farming systems
Crop protection	• Limited basic information on enset bacterial wilt • Limited basic information on other pests • Limited study on epidemiology of enset disease and pests • Limited information on alternative disease and pest control options (eg. Biocontrols etc) • Limited application of molecular diagnostic techniques and management aspects for economically important enset disease and pests (eg. Enset *Xanthomonas* wilt …) • Limited information on pathotype and race evolution mechanisms • Limited study on surveillance and devising management options for newly emerging diseases (e.g. fusarium wilt) • Limited research on integrated pest management
GIS and agro-meteorology	• Limited information for enset suitability map • Limited knowledge on disease and pest prevalence and distribution mapping • Limited information for enset agro-climatology and climate oriented geospatial crop modeling • No information on the effect of climate change on pest and weed intensity
Technology multiplication and seed	• Limited study on macro propagation and phytosanitory techniques

research	• Limited work on planting material multiplication • No study on quality declared seed multiplication protocol • Limited information on enset seed system • Limited work for inspection and certification of the planting materials and propagation techniques
Agricultural Economics, Extension and Gender	• Limited farming system studies • Limited value chain studies • Inadequate studies on enset marketing and technology promotion • Low focus on gender and youth-aware intervention • Limited study on enset technology adoption and impact assessment • Limited study on enset production economics (cost of production)
Agricultural Mechanization	• Limited studies on processing technologies prototype development and multiplication. • Limited study modification of existing processing technologies • Limited study on small-scale processing technologies
Agricultural Qualityand Nutrition Research Laboratory	• Limited studies on nutritional characteristics and quality related traits • Limited studies on industrial potential of enset • There is no well-developed and commercially available starter culture for controlled fermentation • Limited studies on traditional food recipes and industrial values • There is no well-developed laboratory protocols and standards • Limited study on enset Product development and Post-harvest handling
Capacity building	• Limited man power and high turn-over of staff in enset research • Low focus on human power development through short term and on-job training, longterm studies (MSc, PhD), exchange visits and mentoring or experience sharing • Limited infrastructure and facilities • Limited budget allocation, insufficient procurement procedure and delay of budget transfer to run day to day enset research • There is no web-based centralized enset resources
Crosscutting themes	• Gender • Climate change • Knowledge management

The Strategy to Address the Issue

Despite being an orphan crop, enset is supporting more than one-fifth of Ethiopian population and could be considered as a hidden treasure. Yet, it has not attracted a considerable attention from research and funding community in the past. In recent years, however, the gov't has declared enset as a food security and commodity crop and started to support the classical enset research so as to stimulate research on the crop. Agriculture anticipated continues to play the lead role to transform into industrialization in the second five-year growth and transformation Plan (GTP II) of the country.

In context of GTP II plan of the country, the agricultural sector in particular, contribution of enset a commodity could immense pertaining to its multipurpose value, industrial and pharmaceutical applications. In order to exploit the potential contribution of enset, this strategy is designed in such a way that considers the SWOC and PEST aspect of the crop. In addition, the various of organization engaged or likely to engage in enset improvement and product development, potential and previously non-enset growing areas, and strong collaboration and cross-feeding among engaged organization for concerted effort is taken into due consideration. Accordingly, it has been attempted to be client and demand-driven, gender and climate-aware, and participatory to benefit from the indigenous knowledge of farmers.

Therefore, this strategic roadmap document on enset is geared towards three coarse issues that comprehensively touches wider horizon in enset research and could potentially assist to maximize the benefit from enset cultivation and utilization. These are (1) generating basic information on enset, enset disease and pest, and enset associated topics using classical, cotemporary and the state-of-art science (2) strengthening resource capacity for enset research (3) establishing a national forum for enset research and development efforts for concerted efforts.

Accordingly, the research strategy for enset described below is based on the identified thematic areas of the identified issues for the coming 15 years by three phase intervention; short (2016-2020), medium (2021-2025) and long-term (2026-2030) interventions.

Table 4.Strategic issues and interventions

Strategic issues and their thematic areas	Short term (2016-2020) intervention	Medium term (2016-2025) intervention	Long term (2016-2030s) intervention
1. Breeding and genetics research			
Generation of basic information	• Generate basic information on • Catalogues and markers of candidate genes of agronomics importance in enset genome; • Genomic resources for enset (whole genome sequence, transcript, ESTs, protein etc), enset disease and pests, and host-pathogen interaction • Identifying molecular markers on agronomically important traits (eg. Enset Xanthomonas wilt resistance) • Genetic diversity of enset population • Genome wide association mapping for agronomically important traits • Generate basic information on floral biology, ecology and reproduction system in cultivated and wild enset.	• Continue generation of basic information on ; • Catalogues and markers of candidate genes of agronomics importance in enset genome • Genomic resources for enset (whole genome sequence, transcript, ESTs, protein etc), enset disease and pests, and host-pathogen interaction • Identifying molecular markers on agronomically important traits (eg. Enset Xanthomonas wilt resistance) • Genome wide association mapping for agronomically important traits • Enhancing enset genetic resource • Continue generation basic information on floral biology, ecology and reproduction system in cultivated and wild enset. • Undertake crossing studies	• Further continue generation of basic information on; • Markers of candidate genes of agronomics importance in enset genome • Genomic resources for enset (whole genome sequence, transcript, ESTs, protein etc), enset disease and pests, and host-pathogen interaction • Genome wide association mapping for agronomically important traits • Genetics of enset • Enhancing enset genetic resource • Strengthening generation basic information on floral biology, ecology and reproduction system in cultivated and wild enset. • Continue crossing studies
Biotechnology for germplasm enhancement	• Development and optimization of in vitro protocols for different enset landraces	• Development and optimization various in vitro protocols for different enset landraces	• Enhance mutational breeding and evaluate progenies combining with molecular tools

	• Undertake DNA transformation techniques • Undertake mutational breeding in enset (Induction of mutation using different techniques on landraces having agronomically important phenotypically well characterized enset) • Undertake identification of molecular markers linked to agronomically important traits (Eg. resistance to Xanthomonas wilt of enset) • Undertake genomic barcoding of enset cultivars	• Continue DNA transformation techniques • Strengthen mutational breeding and evaluate progenies combing with molecular tools • Continue identification of molecular markers linked to agronomically important traits (Eg. resistance to Xanthomonas wilt of enset) • Apply molecular markers in identification of cultivars identify in the process of evaluation	• Strengthen identification of molecular markers linked to agronomically important traits (Eg. resistance to *Xanthomonas* wilt of enset) • Strengthen applying molecular markers in identification of cultivars identification in the process of evaluation • Undertake marker assisted selection breeding
Germplasm collection, conservation and characterization	• Establish a mechanism for exotic enset species collection • Undertake collection of enset landrace from previously untouched or unexploited areas and conserve at ex-situ field gene bank • Undertake characterization of collections for various traits	• Undertake collection of exotic enset species • Continue collection of enset landrace from previously untouched or unexploited areas and conserve at ex-situ field gene bank • Continue characterization of collections for various traits	• Strengthen collection of exotic enset species • Continue further characterization of collections for various traits
Variety screening and development for various use value as well as for major biotic and abiotic stress	• Identify varieties for non-traditional enset growing areas • Undertake various yield trials for different use values, moisture stress and enset *Xanthomonas* wilt resistance • Undertake evaluation for industrial and pharmaceutical value of enset. • Develop varieties for EBW resistance, *kocho bulla*, fiber, *amicho,* low moisture stress	• Develop varieties for non-traditional enset growing areas • Continue yield trials for different use values, moisture stress and enset *Xanthomonas* wilt resistance • Continue evaluation for industrial and pharmaceutical value of enset • Continue variety development for EBW resistance, *kocho bulla*, fiber, *amicho,* low moisture stress	• Continue variety development for non-traditional enset growing areas • Continue yield trials for different use values, moisture stress and enset *Xanthomonas* wilt resistance • Continue evaluation for industrial and pharmaceutical value of enset • Strengthen variety development for EBW resistance, *kocho bulla*, fiber, *amicho,* low moisture stress
2. Agronomy and physiology			

Cropping systems	• Characterize and classify enset growing AEZs. • Conduct cropping system studies (crop rotaion, mixed cropping, etc.) for sustainable production of enset • Verify available cropping system technologies for different agro-ecology and farming ystem. • System intensification study for different agro-ecology.	• Continue the characterization and classification of agro-ecologies of enset • Continue conducting cropping system studies (crop rotaion, mixed cropping, etc.) for sustainable enset production • Verify available cropping system technologies • Continue system intensification study for different agro-ecology and farming ystem.	• Continue conducting cropping system studies (crop rotaion, mixed cropping etc.) for sustainable enset production • Verify available cropping system technologies • Continue system intensification study for different agro-ecology and farming ystem.
Crop physiology and crop modeling	• Conduct crop physiological studies (water use efficiency, photosynthetic efficeincy, nutrient use efficiency, stress physiology, crop growth and development) • Morpho-physiological traits associated with moisture and nutrient stresses, • Intiate crop modeling stduies in relation to climate change in different enset production systems • Initiate application of biotechnological tools for studies of abiotic stresses	• Continue conduct ing crop physiological studies (water use efficiency, photosynthetic efficeincy, nutrient use efficiency, stress physiology, crop growth and development) • Refine the study on eco-physiological traits associated with stresses. • Continue crop modeling stduies in relation to climate change in different enset production systems • Study the physiology of enset seed and plant growth and development under different AEZs. • Continue application of biotechnological tools for studies of abiotic stresses	• Continue conduct ing crop physiological studies (water use efficiency, photosynthetic efficeincy, nutrient use efficiency, stress physiology, crop growth and development) • In-depth study and exploitation of eco-physiological traits associated with stresses for different AEZs. • Continue crop modeling stduies in relation to climate change in different enset production systems • Continue study the physiology of enset seed and plant growth and development under different AEZs. • Continue application of biotechnological tools for studies of abiotic stresses
3. Soil and water management			
Soil fertility management	• Determine optimum organic and in- organic fertilizer rates, method and time of application for different enset production systems • Develop Integrated Soil Fertility management (ISFM) for different soil types and AEZs • Verify available soil fertility management technologies for different agro-ecology and farming ystem.	• Continue determining optimum organic and in-organic fertilizer rates , method and and time of application for different enset production systems • Continue development of the integrated soil fertility management (ISFM) for different soil types and AEZs • Continue verification of available soil fertility management technologies for different agro-	• Continue determining optimum organic and in-organic fertilizer rates, method and time of application for different enset production systems • Refine and validate integrated soil fertility management (ISFM) for different soil types and AEZs • Continue verification of available soil fertility

		ecology and farming ystem.	management technologies for different agro-ecology and farming system.
Crop response information	• Determine soil test-based crop response information	• Continue determinig soil test-based crop response information	• Continue determinig soil test-based crop response information
Crop water requirement	• Determine water use efficiency and optimiztion techniques	• Continue determinining water use efficiency and optimiztion techniques	• Continue determinining water use efficiency and optimiztion techniques
4. Crop Protection			
Pathology			
Basic information on enset disease	• Variability of major diseases (EBW and other) • Profiles of pathogenicity/virulence factors of major pathogens and host responses • Systemicity of EBW in enset • Start genomics information on mechanism of tolerance/ resistance to major disease (EBW etc) in enset • Beneficial microbes associated with tolerant/resistant enset or their ecology	• Continue variability (phenotypic and molecular) study of major and emerging diseases • Continue genomics information generation on enset-disease interaction • Enhanced studies on profiling pathogenicity/virulence factors and host responses identified • Continue studies on beneficial microbes associated with tolerant/resistant enset or their ecology	• Continue diversity (phenotypic and molecular) study of major diseases • Continue genomics information generation on enset-disease interaction • Enhanced studies on profiling pathogenicity/virulence factors and host responses identified • Continue studies on beneficial microbes associated with tolerant/resistant enset or their ecology
Effect of climate change on enset diseases	• Undertake periodical disease surveys in enset production systems • Study disease dynamics in relation to climate change	• Continue undertaking periodical disease surveys in enset production systems • Continue the study of disease dynamics in relation to changing climate	• Continue periodical disease surveys • in enset production systems • Continue the study of disease dynamics in relation to changing climate
Epidemiology and sources of disease resistance	• Conduct studies on epidemiology of major enset disease (EBW) in enset production systems • Screen enset genotypes against Xanthomonas races enset disease and identify sources of resistance using molecular tools • Indigenous knowledge study on disease control methods identified, documented, and tested	• Continue conducting epidemiology studies of major enset disease (EBW) in enset production systems • Continue Screen enset genotypes against Xanthomonas races enset disease and identify sources of resistance using molecular tools • Continue indigenous knowledge study on disease control methods identified, documented, and tested	• Continue conducting epidemiology studies of major enset disease (EBW) in Enset production systems • Continue Screen enset genotypes against Xanthomonas races enset disease and identify sources of resistance using molecular tools • Continue indigenous knowledge study on disease control methods identified, documented, and tested

Race identification	• Initiate race evolution studies on major enset diseases • Conduct race and pathotype analysis of major enset diseases • Identification of local growth media for EBW Pathogen isolation	• Study and uncover the mechanism of pathotype or race evolution in major enset diseases using standard procedures • Continue race and pathotype analysis of major enset diseases	• Continue studying and uncovering the mechanism of pathotype or race evolution in major enset diseases using standard procedures • Continue race and pathotype analysis of major enset diseases
Molecular studies on disease resistant traits	• Initiate identification of genes for durable disease resistance using marker assisted selections (MAS)	• Continue assessing and identifying genes for durable resistance using marker assisted selections (MAS)	• Contiue assessing and identifying genes for durable resistance using marker assisted selections (MAS)
Quarantine	• Early detecting tools for deadly enset disease (eg. EBW) and other disease imported/developed	• Continue early detecting tools for deadly enset disease (eg. EBW) and other disease developed	• Advanced detecting tools for deadly enset disease (eg. EBW) and other disease imported/developed
Integrated disease management	• Identify effective integrated disease management options	• Continue identification of effective integrated disease management options	• Continue identification of effective integrated disease management options
Entomology	•	•	
Effect of climate change on insect pests	• Undertake enset insect pest surveys periodically in enset production systems • Study insect pest dynamics in relation to climate change	• Continue undertaking enset insect pest surveys periodically in enset production systems • Continue studying insect pest dynamics in relation to climate change	• Continue undertaking enset insect pest surveys periodically in enset production systems • Continue studying insect pest dynamics in relation to climate change
Sources of resistance of major insect pests	• Screen enset landraces for resistance to enset root mealybug • Indigenous knowledge study on pest control methods identified, documented, and tested	• Continue screening enset landraces for resistance to enset root mealy bug • Continue Indigenous knowledge study on pest control methods identified, documented, and tested	• Continue screening enset landraces for resistance to enset root mealy bug • Continue Indigenous knowledge study on pest control methods identified, documented, and tested
Integrated insect pest management	• Identify effective integrated insect pest management options Identify bio-pesticides and evaluate their efficacy on insect pests	• Continue identificaiton of effective integrated insect pest management options • Continue identification of bio-pesticides and evaluate their efficacy on insect pests	• Continue identificaiton of effective integrated insect pest management options • Continue identification of bio-pesticides and evaluate their efficacy on insect pests
Molecular studies on insect pest resistance	• Assess and identify genes for durable resistance using marker assistedselection(MAS)	• Continue assessing and identifying genes for durable resistance using marker assisted selections (MAS)	• Contiue assessing and identifying genes for durable resistance using marker assisted selections (MAS)

	• Conduct biotype analysis and race evolution mechanisms of major enset insect pests	• Continue conducting biotype analysis and race evolution mechanisms of major enset insect pests	• Continue conducting biotype analysis and race evolution mechanisms of major enset insect pests
Weed science			
Weed competitionin in enset production **Climate change on weed infestation** **Integrated weed management**	• Conduct periodical assessment of weed flora in enset production systems • Study the competition effects of grass and broad leaf weeds on enset • Quantify the effect of climate change on the intensity of weeds with their effects on enset production • Identify effective integrated weed management options • Screen effective chmicals for grass weed control in enset fields	• Continue conducting periodical assessment of weed flora in enset production Systems • Continue studying the competition effects of grass and broad leaf weeds on enset • Continue quantifying the effect of climate change on the intensity of weeds with their effects on enset production • Continue identifing effective integrated weed management options • Continue screening effective chmicals for grass weed control in enset fields	• Continue conducting periodical assessment of weed flora in enset production Systems • Continue studying the competition effects of grass and broad leaf weeds on enset • Continue quantifying the effect of climate change on the intensity of weeds with their effects on enset production • Continue identifing effective integrated weed management options • Continue screening effective chmicals for grass weed control for enset production
5. GIS and agro-meteorology			
GIS for operation of farm practices	• Develop GIS based agro-meteorology data for enset production in different production systems	• Continue developing GIS based agro-meteorology data for production of enset in different production systems	• Continue developing GIS based agro-meteorology data for production of enset in different production systems
Enset production suitability map	• Develop enset suitability map using GIS and agro-meteorology	• Continue refining enset production suitability map using GIS and agro meteorology	• Continue refining enset production suitability map using GIS and agro-meteorology
	• Develop enset production constraint map using crop modeling approach	• Continue developing suitability maps for enset production areas using crop modeling approach	• Finalize the suitability map of enset production areas
6. Technology multiplication and seed research			
Pre-basic seedling multiplication	• Determine and develop micro propagation protocols for enset seedling multiplication	• Continue development of micro propagation protocols for enset multiplication	• Continue development of micro propagation protocols for enset multiplication
	• Produce pre-basic seedling of released enset varieties in enough quantity and quality	• Continue producing pre-basic seedling of released enset varieties in enough quantity and quality	• Continue producing pre-basic seedling of released enset varieties in enough quantity and quality
	• Prepare enset seedling production manuals and guidelines	• Prepare laboratory manuals and protocols, seedling inspection procedures/manuals for	• Further continue preparation of manuals and protocols, seedling inspection

		quality control	procedures/manuals for quality control
Community based enset seed production	• Provide technical support to community based seedling producers for production of good quality and quantity of enset seedlings	• Continue providing technical support to community based seedling producers for production of good quality and quantity of enset seedlings	• Continue providing technical support to community based seedling producers for production of good quality and quantity of enset seedlings
7. Agricultural economics, extension and gender			
Enset farming systems	• Survey, diagnose and document the social, economic and cultural values of enset production and its constraints • Document indigenous knowledge on fermentation, food product and post-harvest techniques in different farming system.	• Continue survey, diagnose and document the social, economic and cultural values of enset production and its constraints • Continue documentation of indigenous knowledge on fermentation, food product and post-harvest techniques in different farming system.	• Continue survey, diagnose and document the social, economic and cultural values of enset production and its constraints • Continue documentation of indigenous knowledge on fermentation, food product and post-harvest techniques in different farming system.
Demonstration of enset technologies	• Establish enset information repository (web-based, different information and package delivery mechanisms) • Establish enset parks to provide a platform for other interventions • Participatory demonstration of available and new improved enset technologies in different agro-ecologies • Develop and distribute various communication material (leaf lets, fliers, production manuals) and use mass media to promote dissemination of enset technologies in local languages. • Organize trainings, field days and travelling workshops involving stakeholders to create awareness and popularization of enset technologies • Establish and effectively use innovation	• Strengthen enset information repository (web-based, different information and package delivery mechanisms) • Strengthen enset park to provide a platform for other interventions • Continue participatory demonstration of available and new enset technologies in different agro-ecologies • Continue developing and distributing various communication material (leaf lets, fliers, production manuals) and use mass media to promote dissemination of enset technologies in local languages. • Continue organizing trainings, field days and travelling workshops involving stakeholders to create awareness and popularization of enset technologies • Strengthen and promote innovation platforms for	• Establish enset information repository (web-based, different information and package delivery mechanisms) • Strengthen enset park to provide a platform for other interventions • Continue participatory demonstration of available and new enset technologies in different agro-ecologies • Continue developing and distributing various communication material (leaf lets, fliers, production manuals and mass media) to promote enset technologies in local languages. • Organize trainings, field days and travelling workshops involving stakeholders to create awareness and popularization of enset technologies • Continue strengthening and promoting innovation platforms for development and

	platforms for development and dissemination of enset technologies • Identify best ICT technologies for technology dissemination	development and dissemination of enset technologies	dissemination of enset technologies
Adoption and impact assessment	• Determine the extent of adoption of enset technologies and their impact	• Determine the extent of adoption of enset technologies and their impact	• Determine the extent of adoption of enset technologies and their impact
Value chain	• Conduct value chain study and identify constraints at different stages of the value chain • Establish stakeholder platform to promote enset research and development	• Strengthen value chain study and suggest efficient map • Strengthen stakeholders platform to promote enset research and development	• Strengthen value chain study and suggest efficient map • Strengthen stakeholders platform to promote enset research and development
Gender and youth in enset production	• Enhance the skills and knowledge of youth and women farmers on principles and methods of enset product preparation • Develop working modality to strengthen the participation of women and youth in enset research and promotion • Characterize and mainstream gender roles and perspectives in enset research and development	• Enhance the skills and knowledge of youth and women farmers on principles and methods of enset product preparation • Develop working modality to strengthen the participation of women and youth in enset research and promotion • Promote gender main streaming in enset research and development	• Enhance the skills and knowledge of youth and women farmers on principles and methods of enset product preparation • Develop working modality to strengthen the participation of women and youth in enset research and promotion • Promote gender main streaming in enset research and development
8. Agricultural mechanization			
Mechanization technologies	• Modify, design and develop enset processing mechanization/farm tools technologies suitable to different enset and affordable to smallholders. • Provide prototypes to enterprises for wide multiplication and distribution	• Modify, design, and develop enset processing mechanization/ farm tools technologies suitable to different enset and affordable to smallholders. • Provide prototypes to enterprises for wide multiplication and distribution	• Modify, design, and develop enset processing mechanization/ farm tools technologies suitable to different enset and affordable to smallholders. • Provide prototypes to enterprises for wide multiplication and distribution
9. Agricultural quality and post-harvest			
Nutritional and industrial potential of enset	• Assess nutritional quality of enset varieties and associated food products • Assess industrial potential of enset starch and fiber quality	• Assess nutritional quality of enset varieties and associated food products • Assess industrial potential of enset starch and fiber quality	• Continue assessing nutritional quality of enset varieties and associated food products • Assess industrial potential of enset starch and fiber quality

Enset Product development and Post-harvest handling	• Develop enset -based alternative and fortified food products • Develop recipes for enset-based alternative and fortified food product • Identify/determine post-harvest handling problems and losses • Identify/determine enset product (Kocho, bulla and fiber) management (handling and storage) technologies, • Establish standard specifications of some raw and finished products • Start controlled fermentation studies with selected culture strata	• Develop enset -based alternative and fortified food products • Develop recipes for enset-based alternative and fortified food product • Identify/determine post-harvest handling problems and losses • Continue development of enset product (Kocho, bulla and fiber) management technologies, • Establish standard specifications of some raw and finished products • Continue development and optimization of controlled fermentation studies with selected culture technologies	• Develop enset -based alternative and fortified food products • Develop recipes for enset-based alternative and fortified food product • Identify/determine post-harvest handling problems and losses • Enhance development of enset product (Kocho, bulla and fiber) management technologies, • Establish standard specifications of some raw and finished products • Enhance development and optimization of controlled fermentation studies with selected culture technologies
10. Capacity building			
Limmited manpower and high staff turnover	• Recruit qualified researchers for all disciplines • Device incentive mechanisms to retain staff • Create conducive working environment	• Maintain adequate level of qualified research staff	• Maintain adequate level of qualified research staff
Man power development	• Strengthen capacity and familiarize researchers with modern scientific tools through long and short term trainings and periodical mentorship • Organize short term and on-job trainings for support staff • Organize experience sharing and exchange visits	• Strengthen capacity and familiarize researchers with modern scientific tools through long and short term trainings and periodical mentorship • Organize short term and on-job trainings for support staff • Organize experience sharing and exchange visits	• Strengthen capacity and familiarize researchers with modern scientific tools through long and short term trainings and periodical mentorship • Organize short term and on-job trainings for support staff • Organize experience sharing and exchange visits

Facilities and infrastructure for Enset research	• Strengthen enset research capability in coordinating center (Areka) and other four (Holleta, Jimma, Hawassa, and Kulumsa) enset research centers • Provide adequate infrastructure for different research centers (e.g. offices, greenhouses, libraries/ICT, residential houses, social center, cold rooms, water supply, power supply, and land development and testing sites) • Provide adequate land and farm machinery for breeder and pre-basic seedling multiplication • Provide vehicles, office, field and laboratory equipment	• Strengthen enset research capability in coordinating center (Areka) and other four (Holleta, Jimma, Hawassa, and Kulumsa) enset research centers. • Provide adequate infrastructure for different research centres (e.g. offices, greenhouses, libraries/ICT, residential houses, social center, cold rooms, water supply, power supply, and land development and testing sites) • Provide adequate land and farm machinery for breeder and pre-basic seedling multiplication • Provide vehicles, office, field and laboratory equipment	• Strengthen enset research capability in coordinating center (Areka) and other four (Holleta, Jimma, Hawassa, and Kulumsa) enset research centers. • Provide adequate infrastructure for different research centers (e.g. offices, greenhouses, libraries/ICT, residential houses, social center, cold rooms, water supply, power supply, and land development and testing sites) • Provide adequate land and farm machinery for breeder and pre-basic seedling multiplication • Provide vehicles, office, field and laboratory equipment
Budget allocation and procurement	• Allocate adequate budget, • Improve the procurement process and release budget timely	• Allocate adequate budget • Improve the procurement process and release budget timely	• Allocate adequate budget, • Improve the procurement process and release budget timely
Crosscutting Themes			
Gender **Climate change** **Knowledge management**	• Consider gender equality and ensure that woman get their fair share of the benefits of research results; Since climate change is becoming a challenge, ensure that research programs would adequately address the challenge to increase resilience of vulnerable communities; and consider modern facilities of ICT are instrumental in knowledge and information transfer processes		

The Next Steps

In order for the strategy to be implemented in a coherent way, it is indispensable to develop a clear implementation plan. The strategic plan document should be viewed as a living constantly assessing the external and internal environment for changes regarding emerging opportunities or challenges, internal weaknesses and strengths as well as political, economic, socio-cultural, environmental, technological and legal challenges. The strategies and strategic plan should respond to the new external and internal environments. Therefore reviewing the strategic plan monitoring and evaluation, impact assessment and reassessment of the strategies and strategic plan should be done as required.

Annexes

Annex 1. Area, Production and Yield of Enset Crop for Meher Season 2011/12- 2015/16 E.C

Cropping year	Number of trees harvested	Production In Quintals			Total Production (Quintals)	Yield (Quintals/Tree)		
		Amicho	*Kocho*	*Bula*		*Amicho*	*Kocho*	*Bula*
2015/16	112522152	23821849.47	28329103.94	950414.35	53101367.76	0.21	0.25	0.01
2014/15	98002435	22929729.9	26219341.2	1022800.3	50171871.4	0.23	0.27	0.01
2013/14	130630473	31143132.27	34720355.36	1225934.66	67089422.00	0.24	0.27	0.01
2012/13	113999188	10936627.60	12985122.73	461,280.87	24383031.20	0.10	0.11	*
2011/12	312,171.98 hectares of land				7288686.96			

Potato Research Strategy

[69]

Introduction

Potato is among the few crops that the great majority of farming households in the cool highland areas of Ethiopia predominantly rely on as a source of food. It is probably the single commodity so universally relished in Ethiopian dishes invariably in the urban and rural settings all across the country. Its contribution to fill the food gap inexorably confronted by so many food-insecure areas and households during the lean periods of the year is particularly invaluable. In terms of area, potato with 0.3 million hectares accounts for 60% of the area under root crops and 29% under all horticultural crops; and production wise, with 3.66 million metric tons, it accounts for corresponding figures of 51 and 43 percent. It is also worth to note that with only 2.5% of the total area allotted to cereals, potato represents an equivalent of more than 14% of their production volume; which signifies the potential of potato in mitigating the ever widening gap between relentlessly rising population, and thus spiking food demand on hand and dwindling natural resource base and global climate change on the other.

Scientific research on potato began in 1973 by the then Alemaya College of Agriculture (now Haramaya University) in cooperation with the Institute of Agricultural Research (now EIAR) and the International Potato Center (CIP). However, a more-coordinated and multidisciplinary research with a much broader coverage of potato-growing regions of the country evolved following the transfer of the program to Holetta Agricultural Research Center in 1975. In 2005, the coordination was reassigned to Adet Agricultural Research Center. During the past one decade alone, the research registered remarkable results including the release of 16 disease-resistant, adaptable, and high-yielding varieties along with their packages of agronomic practices suitable for specific agro-ecologies; and disease management options.

Although a comprehensive potato research strategy was developed in the late 1990's during the tenure of EARO it was not implemented in its entirety due mainly to structural changes in the research system. In pursuit of delivering outputs matching national and sectoral economic drives; and aligned to the Government's development policy frameworks, EIAR is now impelled to develop a new research strategy for potato. The National Potato Research Program has prepared this long-term research strategy (2016-2030); which was drafted by building on the experiences and lessons gained from the previous strategy that was followed through, sparsely as it was, over the last fifteen years. This new research strategy has been developed by a multi-disciplinary team of researchers working on potato to: serve as

the central document guiding their efforts for the next 15 years; and provide an all-inclusive framework for prioritizing and coordinating research activities towards the achievement of shared- vision and objectives.

The strategy is organized in six major chapters whereby this background section together with descriptions of the rationale, vision, mission, goal and objectives constitute the introductory chapter 1. Chapter 2 provides an overview of the importance of potato in the Ethiopian agriculture; and food and nutrition security. Chapter 3 briefly discusses the situation analysis undertaken by assessing the internal environment as well as the external one involving all the key stakeholders to capture their reflections, concerns and desires. In chapter 4 are presented the critical issues that have been sifted out from the situation analysis and articulated as key challenges facing the program. Chapter 5 discusses the actual strategic interventions to be pursued under the various thematic areas of the research to tackle the critical issues identified. Chapter 6 provides key elements of follow up documents that need to be worked out in the next steps as they are prerequisites for effective implementation of the strategy.

Rationale

Lessons learned over the last several years indicate that judicious dissemination and application of proven technologies and inputs will bring about significant and positive changes in both the production and productivity of potato and the wellbeing of the producers. Cognizant of the available physiographic and climatic settings suitable for potato production coupled with conducive policy and regulatory frameworks put in place, potato can play a key role to: ensure food and nutrition security for millions of small-scale farming households; strengthen the opportunity for job creation and income generation; foster expansion of agro-industries, agri-business and import substitution; diversify the base for foreign earnings; and stabilize the macro-economy in general.

Therefore, the need for maximizing utilization of potential agro-climatic, physiographic and hydrologic conditions of the country to increase production, productivity and marketability of potato is a matter of urgency. In the present context though not only is wide the gap between what is available at research level and how much of that is being used by the farmer; but also are little the results attained thus far by the research system in comparison with the potential that could be realized from the crop. In order to create a condition where these divergent scenarios could converge and thus the commodity's potential could best be exploited, it is absolutely necessary to develop a well-defined and an all-inclusive research strategy representing and addressing the interests of all the key stakeholders involved in

potato value chains. Such a strategy not only creates a stronger cohesion and partnership among stakeholders but also serves as a roadmap to: guide the research program planning and implementation in line with the objectives and targets of GTP-II and that of EIAR; track records of results and lessons; and mobilize resources from national and/or international sources. It is with this rationale that the National Potato Research Program (NPRP) - Team has developed this Research Strategy to achieve a common vision and objectives.

The NPRP -Team has a strong conviction that a thriving future for the commodity can be achieved only if it involves meaningful collaborations between farmers, input suppliers, exporters, actors in agribusiness and agro-industry, traders, technicians, scientists, and others engaged in the value chains. To this end, the research team has formulated a set of principles and values that reflect its vision, mission, goal and objectives underpinning its commitments and desires as indicated below.

Vision

The vision of the National Potato Research Program (NPRP) is to be a competent research program availing technological innovations and knowledge that can significantly contribute to improved livelihoods and provision of competitive products for manufacturing industries and export market.

Mission

The mission of the NPRP is to conduct agro-ecology- and product- based research, generate, adapt and transfer technologies and knowledge that are acceptable by users for improving productivity, nutritional quality and sustainable development of agriculture, agribusiness and export market.

Goal

The goal of the NPRP is to contribute to the EIAR's role towards the achievement of the sectorial objectives of ensuring food security, sustainable delivering of raw materials for agro-industries and import substitution, expanding the bases for the country to gain foreign earnings from agricultural exports, and increasing livelihood resiliency and environmental sustainability while reducing vulnerability to climate change.

Objectives

The overall objective of the NPRP is to increase the production, productivity, quality and versatility of potato through multidisciplinary and participatory research approach leading to its increased share in the national economy and advancement. Specific objects of the program, among others, include the following:

- To generate and adapt potato technologies that can sustainably enhance productivity and quality to leverage its role in the food security, provide sustainable raw materials for manufacturing firms, import substitution and hard currency earnings ;
- To collect, characterize and conserve potato genetic resources for research use ;
- To generate and adapt potato technologies that can reduce child mortality and women health problems associated with malnutrition and thereby contribute to building a healthy and productive society and
- To generate technologies that provides competitive products for micro-processing businesses and creates jobs for rural and urban women and youth.

Importance of Potato

Although Ethiopia is neither the center of origin nor diversity for potato, it has free access to germplasm from the International Potato Center (CIP) which is the custodian of the biggest potato gene bank owing to its global mandate of furnishing needy-countries with genetic resources for public goods. In Ethiopia potato is grown in a wide range of agro-ecologies almost all through the year using the main- as well as belg- season rains, irrigation and residual moisture; thus allowing a continuous supply of fresh potato throughout. Agricultural areas in the northwest, central, south and south east represent the highest production of potato where more than 5 million smallholders farmers are engaged with a total area of around 0.3 million hectares producing about 3.7 million tons of potato annually. The national average productivity of potato has enormously increased from 5.7 MT/ha in the early 2000's to the present 12 plus MT/ha due partly to the coverage of improved varieties accounting for 25.2% of the total land cultivated under potato. Potato produces more food (dry matter) and protein per unit area; and more food per unit of water than any other major crop. A hectare of potato can feed 22 persons a year compared to rice of equivalent area feeding 19 persons. Potato yields approximately three times more energy than wheat, barley and oats. Hence, just 0.20 hectare of potato can cover the total annual energy demands of a family of two adults and three young children.

Over 65% of the potato produced in Ethiopia is meant for household consumption, mainly eaten boiled and for cooking stew. Since recently, however, other forms of utilization such as in making breads, cookies, Injera, complementary child foods, local drinks, and chips are evolving in towns; giving a new opportunity for agro-processing enterprises especially for the jobless youth. Nutritionally potato is an excellent source of carbohydrate, vitamins, minerals and the essential amino acid lysine which is used to fortify cereal products such as rice and pasta. It is a complete diet if consumed with milk for vitamin A supplement. With technologies useful for drying, potatoes can be turned into powder and thereby extend its shelf life to ensure sustainable food supply. Other branded-products could be developed for extraction of starches being used in textile, packaging, printing, and glue industries which at present are covering their needs exclusively imported products. While boarder trades in Djibouti, Somalia and Sudan represent a longstanding market-relationship, the potential of potato in earning foreign currency even beyond this traditional route is sizeable.

Situation Analysis

Two categories of forces and factors influencing the conception, formulation, action and implementation of the strategy were analyzed as external and internal factors. The external factors (influences that are outside the research system) represent both the interests of stakeholders that the research should serve and the potential role that they can play to complement or synergize the research. Specific situations or stakeholders' interests that hold back research stride or the research falls short to positively respond to, represent the challenges (C); while those that create motivation for the research represent the opportunities (O). Therefore, the situation analysis of the external factors essentially examined Opportunities and Challenges (OC) presented from the existing Political /Policy /Legal, Economic, Educational, Socio-cultural, Technological/ Technical, and Environmental (PEST) perspectives of the factors. Almost all key stakeholders, notably the Ministries of: Agriculture and Natural Resources, Trade and Industries; exporters; private industries; farmers' unions; various relevant technical units of EIAR; the Regional Research Institutes and centers; and Higher Learning Institutions involved in Sub-tropical Fruit Crops research have taken part in the process.

Analysis of the internal situation (influences that are outside the research system) was made by scrupulously examining whether or not there is the capacity within the research system that can readily be deployed by the team to deliver outputs or promptly respond to stakeholders' quests or challenges. While the presence of such a capacity denotes the strength (S) of the team; the capacity which is required to deliver desirable outputs but falls short to exist represents the weakness (W). Therefore, analysis of the situation of internal factors examined Strengths and Weaknesses (SW) of the research team in terms of the existing resources (human, physical and fiscal); inter- and intra-disciplinary integrations, complementarities and synergies; availability of technologies, information and knowledge; and organization of internal system, and geographic coverage of the research program.

The results from the situation analysis were finally consolidated in a form of metrix whereby prevailing strengths, weaknesses, opportunities, and challenges (SWOC) were narrated with respect to their relevance to the various thematic areas that the research team is engaged in. From the situations narrated as such then were formulated the issues that the research system needs to address in the short-,

medium-, and long- term plans. Experiences of other countries with respect to the level they have reached in research and development aspects of Sub-tropical fruit crops were also examined to set a benchmark for the strategy.

Strategic Issues

The major strategic thematic areas identified for the Potato Research Program include: Genetics and breeding; Agronomy and physiology; Technology multiplication and seed research; Crop protection; Irrigation water and nutrient management; Agricultural economics; Agricultural research extension and gender; Agricultural mechanization; Food science, postharvest management and value addition; GIS and Agro-meteorology; Capacity building; and Additional cross-cutting themes. Specific strategic issues pertaining to each thematic area are presented under Table 1.

Table .1 Strategic issues facing the National Potato Research Program and their relevance in the short-, medium- and long- terms

Thematic area	Strategic issue	Relevance in the		
		Short-term (1-5 years)	Medium-term (6-10 years)	Long-term (10-15 years)
Genetics and breeding	• Narrow genetic base and lack of diversity within the local genepool that can readily be deployed for improvement programs; • Lack of varieties resistant to major diseases; • Limited options of varietal choices for: extreme cool highlands, humid-midland areas with long-rain durations, areas with short rain/belg systems, drought-prone areas, and lowland areas with high day and night time temperatures; • Lack of varieties developed for irrigated production systems; • Lack of varieties suitable for processing purposes (French fries, crisps, salad, canning); • Lack of biofortified or nutritionally enhanced potato varieties and • No basic genetic information guiding the breeding work has been established for the widely grown local or improved varieties or advanced/elite materials in the breeding program.	x	x	x
Agronomy and physiology	• Inadequate packages of recommendations/technologies on cropping systems (mixed/inter-cropping, double cropping, crop rotation and cropping sequence) to fit potato in different production systems ; • Inadequate packages of agronomic practices (planting time, density, fertilizer type, rate, method and time of application, etc.) specific for different growing areas/production systems ; • Inadequate information on stress (drought, heat, frost, etc.) physiology ; • Lack of information on nutrient use efficiency of available potato germplasms to suit to farmers of different economic strata in terms of access to commercial fertilizers and • Lack of information on potential of potato to fit in systems pursuing conservation agriculture (CA) and climate-smart agriculture enhancing adaptation to and/or mitigation of climate change.	x	x	x
Technology multiplication and seed research	• Shortage of good-quality planting material of improved varieties and weak quality control system; • Inadequate information on potato seed science.	x	x	x
Crop protection	• Inadequate information on races of pathogens causing major diseases on potato (Phytophtera infestans, Ralstonia solanacearum and others) ;	x	x	x

	• Inadequate information on the biology, ecology, and population dynamics of important insect pests and vectors ; • Inadequate information on the epidemiology of major diseases affecting potato in different agro-ecologies and production systems ; • Inadequate IDM and IPM packages against diseases, insects and vectors ; • Inadequate disease management packages against bacterial wilt and • Absence of delineation of areas best suited for seed production or pest-risk zones to be precluded for seed-multiplication.			
Irrigation water and nutrient management	• Inadequate packages of recommendations on: macro-, micro-, inorganic and organic (compost, vermicompost, farmyard manure, green manure) fertilizers appropriate for different production (rain-fed, belg, moisture-stress, and irrigated) and processing (optimum nutrient concentrations in the tubers) scenarios ; • Inadequate information on water requirements and irrigation scheduling ; • Lack water-efficient irrigation technologies/systems appropriate for different agro-ecologies and soil types and • Lack of information on critical water depletion levels (crop coefficient-Kc) for different varieties and developmental stages.	x	x	x
Agricultural economics	• Inadequate information on characterization and diagnostics of potato-based farming systems, value chains and market efficiencies; • Inadequate feedback-information on technology adoption rate, diffusion intensity and impact and • Inadequate information on economics (technical and economic efficiencies) of potato production under smallholder grower's conditions.	x	x	x
Agricultural extension and gender	• Lack of gender-disaggregated information across the value chain of potato; • Inadequate knowledge and skill of farmers and agricultural experts on improved potato technologies ; • Inept and wasteful traditional methods used by key actors in the value chain to transport, market, process and consume potato and • Lack of well-consolidated and networked data base that can easily be accessed by users at all levels.	x	x	x
Agricultural mechanization	• Lack of agricultural machinery, implements and equipment for pre- and post- harvest operations (row planters, weeders, fertilizer-placers, cultivators, harvesters/lifters and graders) of potato under small-scale growers' conditions.	x	x	x

Food science, postharvest management and value addition	• Inadequate information on nutritional and physicochemical characteristics of improved varieties, elite materials and the available germplasm ; • Limited technologies of value-addition through semi-processing, full-processing, packaging and storing and • Heavy post-harvest loss and lack of management technologies to tackle the problem.	x	x	x
GIS and Agro-meteorology	• Lack of spatial suitability analyses, mapping, climate characterization and crop modeling.	x	x	x
Capacity building	Inadequate resources • Physical • Human • Finance	x	x	x
Additional crosscutting themes	• Climate change and knowledge management.	x	x	x

Note the mark "X" denotes that the issue is relevant and needs to be tackled

Research Themes and Strategic Interventions

Most of the research issues identified to be addressed by the potato research team are multi-institutional, multi-thematic, multidisciplinary, participatory, and need to be implemented in collaboration with farmers, extensionists and a wide range of other partners to be involved in the whole spectrum of the value chains. The research themes are built on the disciplinary as well as crosscutting themes briefly discussed hereunder. The strategic interventions proposed to tackle each of the issues identified for each theme, and need to be implemented during the next fifteen years on the: short-, medium- and long- term basis, are presented in Table 2 following the narrations of the disciplinary and cross-cutting thematic areas.

Research Themes

Genetics and breeding

In the years ahead, the potato sub-sector foresees a steady demand for varieties with higher and more stable yields and acceptable quality. To keep pace with this demand, much of the focus will be on developing new varieties that are high yielding, adapted to a variety of environments, and resilient in the face of multiple stresses such as climate change, emergence of new pests and diseases, and other biotic and abiotic factors. The strategy will generally seek to accelerate crop improvement by using both conventional and modern methods and technologies that make possible handling of large volumes of genetic material and select with greater precision. This will involve stronger integration of conventional plant breeding approaches with modern tools and methods of biotechnology.

Agronomy and physiology

Keeping the principle of eco-efficiency, the agronomy and crop physiology endeavor will focus towards developing improved crop management practices that open the way for optimal expression of genetic potential of varieties and enhancing the physiological and agronomic efficiency of the crop.

Technology multiplication and seed research

The core of research activities envisioned by the technology multiplication and seed research component of the strategy will be to:

identify key problems associated with producing sufficient quantity and quality of initial material by generating basic information that would help to develop technologies addressing the challenges; adopt advanced tools of tissue culture for developing disease-free planting material of; identify and adopt good practices of technology multiplication for large-scale production of the crop; and devising an internal system whereby expeditious multiplication of high-quality planting material would be effected in order to meet ever growing demand.

Crop protection

To make crop production more eco-efficient is to achieve yield stability and reduce the chances of crop failure due to diseases and other pests, whose dynamics are shifting as a result of climate change. To this end, the research will focus on both host plant resistance and biological control with greater emphasis to integrated approaches of controlling diseases, insect pests, weeds and vertebrate pests through Integrated Pest Management (IPM) systems.

Irrigation water and nutrient management

Development of water-efficient management practices including micro-irrigation, fertigation, irrigation scheduling, etc. constitute arears of intervention related to production of potato as it is best fitting for production under irrigation conditions.

Agricultural economics

Agricultural economics is among the core themes of research as it plays a vanguard role in linking the biological sphere of the research and the economic validity of the results when actually being implemented by the farmer or other targets in the recommendation domains. Furthermore, it has also a key role to play in addressing policy issues that are instrumental in developing and promoting efficient, functional and sustainable value chains of potato.

Agricultural extension and gender

The agricultural extension and gender component of the research brings in stakeholders together to formulate relevant research agenda as it does also take out promising research results to the demonstration and extension processes. Nevertheless the role the extension component plays in addressing the social aspects of the research, it is the main channel for the two-way flow of information between the research system on one hand and the end users of the research results on the other. Therefore, addressing issues related to socio-economic

and research extension in the strategy is vital to attain the successes that the research team envisages. It will also be crucial to address issues related to gender equality and inclusiveness of the research process in general through this component.

Agricultural mechanization

The main challenges associated with agricultural machinery and post-harvest handling is the fact that producers in Ethiopia had little opportunity to employ small-scale farm implements, water pumps for irrigation, means of transportation, and storage structures that are appropriate for potato. Both pre- and post- harvest operations are done manually using age-old traditional methods. Losses in both quantities and qualities associated with these manual and dated practices are often appalling. It is therefore, imperative to consider this field of research in this research strategy.

Food science, postharvest management and value addition

Potato has a great deal of potential in the food industry. It is therefore, essential to work on chemical characterization and profiling of the available varietes and eventually the genepool for nutritional as well as industrial values. It is also critical to develop recommendations on post-harvest technologies that would improve shelf life of the produce. Establishing alternative ways of processing the produce in view of increasing their shelf life will also open up a new vista of value addition and product diversification and thus better market opportunities for producers and options of choices for consumers.

GIS and agro-meteorology

In formulating strategic interventions to be harnessed for achieving the objectives stipulated from the outset, it will be given due attention to GIS and agro-meteorology for better understanding of the dimensions of local climate and farming systems (physical climate, social, economic, farming systems, etc.) for targeting and developing the right technology for the right environment.

Capacity building

Two important issues were identified under this topic: the need for strengthening the capacity of the research team; and the stakeholders involved in the value chains in general need to have a strong, functional, influential and sustainable forum that will shape up the future of the research, production, processing, trade, and consumption of the commodity.

Crosscutting themes

Gender: The role of women in the agricultural system is critical as women contribute 70 percent of farm labour at harvesting and in post-harvest activities. But women farmers have only limited access to resources, services, land and credit. Unequal gender relations often make women more vulnerable to the effects of poverty, land degradation, and climate change. If the gender gap were eliminated, FAO asserts that total agricultural output would increase. Cognizant of this, the strategy upholds integration of gender concerns into research objectives, technology development, extension, and evaluation frameworks.

Climate change: In Ethiopia, climate change is already having an impact on the livelihoods of different communities in different corners of the country. Therefore, the research strategy will place due considerations to availing technologies that would help actors in the value chains to respond to climate change through adaptation and/or mitigation approaches.

Knowledge management (KM): Through KM interventions aided by new information technologies, it is possible to help improve smallholders' access to resources that help them improve their farm productivity and competitive ability. KM will also help to create research products in a more collaborative manner that makes them more suitable for diverse audiences. For this purpose, the research team will make results more readily available by spearheading formations of multi-stakeholder platforms that facilitate interaction and promote learning for change, mentoring, and networking.

Strategic Interventions

Table 2 Strategic interventions planned to address critical issues facing the National Potato Research Program in the short-, medium- and long- terms

Thematic areas	Strategic Interventions		
	Short term (5 years)	Medium term (10 years)	Long term (15 years)
5.2.1 Genetics and breeding			
Narrow genetic base; lack of varieties: with resistance to diseases, tolerance to extreme cool highland, adaptable to humid-midland with long-rainfall duration, areas with short rain/belg systems, drought-prone areas, lowland areas with high day and night time temperatures, suitable for irrigated-production systems, processing, and nutritionally enhanced/ biofortified; and lack of basic genetic information	• Broaden the genetic base by introducing germplasms from all possible external sources; • Generate variability through planned crossing between and/or among the local populations and introduced materials; • Introduce and adapt commercial varieties proved to be viable elsewhere for certain specific targets and objectives; • Adapt and optimize screening techniques for resistance breeding against important biotic stresses (fungi, bacteria, virus, insects) • Develop varieties: with resistance to diseases, tolerance to extreme cool highland; adaptable to humid-midland with long-rainfall duration, areas with short rain/belg systems, drought-prone areas, and lowland areas with high day and night time temperatures; and suitable for irrigated-production systems; • Evaluate the existing varieties, elite and germplasm materials for processing qualities and nutrient content; • Develop varieties biofortified for desirable contents of Fe and Zn and better nutritional	• Broaden the genetic base by introducing germplasms from all possible external sources; • Generate variability through planned crossing between and/or among the local populations and introduced materials; • Introduce and adapt new commercial varieties proved to be viable elsewhere for certain specific targets and objectives; • Adapt and optimize molecular techniques for resistance breeding against important biotic factors (fungi, bacteria, virus, insects); • Develop new varieties: with resistance to diseases, tolerance to extreme cool highland; adaptable to humid-midland with long-rainfall duration, areas with short rain/belg systems, drought-prone areas, and lowland areas with high day and night time temperatures; and suitable for irrigated-production systems; • Strengthen evaluation of the existing varieties, elite and germplasm materials for processing qualities and nutrient content; • Develop new varieties biofortified for	• Broaden the genetic base by introducing germplasms from all possible external sources; • Generate variability through planned crossing between and/or among the local populations and introduced materials; • Introduce and adapt new commercial varieties proved to be viable elsewhere for certain specific targets and objectives; • Strengthen and refine application of molecular techniques for resistance breeding against important biotic factors (fungi, bacteria, virus, insects); • Develop new varieties: with resistance to diseases, tolerance to extreme cool highland; adaptable to humid-midland with long-rainfall duration, areas with short rain/belg systems, drought-prone areas, and lowland areas with high day and night time temperatures; and suitable for irrigated-production systems; • Develop improved varieties with high levels of tolerance to abiotic stress factors

	quality ; • Study and establish such basic information as: genetic diversity, breeding values, adaptation range, etc. of the existing potato germplasm and • Prepare a catalogue of varieties registered to date under different institutions.	desirable contents of Fe and Zn and better nutritional quality ; • Refine the basic information on: genetic diversity, breeding values, adaptation range, etc. of the existing potato germplasm and • Update the catalogue of registered potato varieties.	using biotech tools (molecular characterization and in-vitro marker-assisted selection techniques); • Refine evaluation of the existing varieties, elite and germplasm materials for processing qualities and nutrient content; • Develop new varieties biofortified for desirable contents of Fe and Zn and better nutritional quality and • Update the catalogue of registered potato varieties.
5.2.2 Agronomy and physiology			
Inadequate packages of recommendations/ information on: cropping systems, area-specific agronomic practices, stress physiology, nutrient use efficiency, potential of potato to suit for conservation agriculture and climate-smart agriculture (	• Fine tune existing agronomic practices proved to be effective on both farmers' and research fields and update and resynthesize recommendation packages to fit to specific agro-ecologies, varieties, growing conditions ; • Develop technologies and packages of recommendations on potato-based cropping systems (mixed/inter-cropping, double cropping, crop rotation and cropping sequence) appropriate for rain- fed production conditions; • Develop packages of agronomic recommendations appropriate for specific purposes (seed *vs* ware potatoes), agro-ecologies and growing conditions (rain- fed *vs* irrigated); • Determine mechanisms of tolerance/resistance to abiotic/biotic stresses; • Determine morpho-physiological traits embedding tolerance to different factors of abiotic stress;	• Strengthen development of technologies and packages of recommendations on potato-based cropping systems appropriate for both rainfed and irrigated potato production; • Refine packages of agronomic recommendations appropriate for specific purposes (seed vs ware potatoes), agro-ecologies and growing conditions (rain -fed vs irrigated); • Strengthen research and refine results on mechanisms and morpho-physiological traits embedding tolerance to different factors of abiotic stress; including induced-stress conditions under growth chamber or in-vitro culture; • Strengthen profiling new varieties and germplasm with respect to nutrient-use efficiency; and develop options of varieties with gradients of nutrient-use efficiencies (along with appropriate agronomic practices)	• Strengthen development of resource-efficient (land, labor, capital, time) technologies and packages of recommendations on potato-based cropping systems appropriate for both rainfed and irrigated production conditions; • Refine packages of agronomic recommendations appropriate for specific purposes (seed vs ware potatoes), agro-ecologies and growing conditions (rain-fed vs irrigated); • Strengthen research and refine results on mechanisms and morpho-physiological traits embedding tolerance to different factors of abiotic stress using modern throughput techniques and technologies and • Strengthen profiling new varieties and germplasm with respect to nutrient-use

	• Profile the existing varieties and elite and germplasm materials with respect to their nutrient-use efficiency and • Generate information on potential of potato to fit in systems pursuing conservation agriculture and climate-smart agriculture enhancing adaptation to- and/or mitigation of- climate change; and develop recommendations to make use of the potential, if any.	to respond to farmers of different economic strata in terms of access to commercial fertilizers and • Refine packages of recommendations to make best use of potato for conservation and climate-smart agriculture.	efficiency; and develop options of varieties with gradients of nutrient-use efficiencies (along with appropriate agronomic practices) to respond to farmers of different economic strata in terms of access to commercial fertilizers.
5.2.3 Technology multiplication and seed research			
Shortage of good-quality planting material of improved varieties; weak quality-control system; and inadequate information on potato seed science	• Identify gaps, at institution, legislation or policy levels, that need to be promptly addressed to invigorate the potato seed system; and prepare and present to EIAR-top management a policy brief and/or recommendation ; • Multiply good-quality initial planting materials through conventional and/or unconventional techniques and promote their distribution; • Develop new techniques and methods of fast production of large quantities of good-quality early-generation seed ; • Determine: rate of degeneration of seed quality; and extent and causes of post-harvest seed losses at different seed production areas; • Develop options of management packages/technologies against: vectors; dormancy; and post-harvest seed losses and • Develop: the internal seed-quality control system; and packages of recommendations/ technologies for on-farm production and multiplication of planting material.	• Multiply good-quality initial planting materials through conventional and/or unconventional techniques and promote their distribution ; • Strengthen development of options of management packages/technologies against: vectors; dormancy; and post-harvest seed losses and • Strengthen: the internal seed-quality control system; and packages of recommendations/ technologies developed for on-farm production and multiplication of planting material.	• Multiply good-quality initial planting materials through conventional and/or unconventional techniques and promote their distribution ; • Refine options of management packages/technologies against: vectors; dormancy; and post-harvest seed losses and • Refine: the internal seed-quality control system; and packages of recommendations/ technologies developed for on-farm production and multiplication of planting material.

5.2.4 Crop protection			
Limited information on: races of major pathogens, biology, ecology, and population dynamics of major insect pests and vectors, and epidemiology of important diseases; inadequate IPM packages against diseases, insects and vectors; inadequate disease management packages against bacterial wilt; and absence of delineation of pest-risk zones for seed-multiplication	• Collect, determine and characterize races of the major pathogens using differentials; • Develop a baseline information on agro-ecological distributions of insect pests and vectors inflicting damages on potato; • Introduce and adapt IDM and IPM methods against major diseases, insect pests and vectors of potato ; • Undertake studies to understand: soil-health factors aggravating bacterial wilt; and dynamics of insect pests causing seed-health deterioration; and develop packages of recommendations/ technologies against these culprits and • Create awareness about integrated disease management through: developing and distributing simple handheld pocket guides; using multiple communication media; and advocacy for legislative support.	• Refine the race identification and characterization work using molecular and serological diagnostic techniques; • Undertake studies on host ranges of pathogens of potato and refine packages of IDM practices; • Generate information on: the biology, ecology, and population dynamics of major insect pests and vectors; • Generate information on: the ecology, epidemiology, race/biotypes, and dynamics of the major diseases; • Refine the IDM and IPM methods developed against major diseases, insect pests and vectors in light of information from the basic studies above; • Develop: methods for undertaking surveillance and monitoring on the emergence and dynamics of new and known pests and vectors; early-warning systems; and packages of management practices against the pests and vectors and • Strengthen awareness creation about integrated disease management through: developing and distributing simple handheld pocket guides; using multiple communication media; and advocacy for legislative support.	• Strengthen the race identification and characterization work using molecular and serological diagnostic techniques; • Refine information on: the biology, ecology, and population dynamics of major insect pests and vectors; • Refine information on: the ecology, epidemiology, race/biotypes, and dynamics of the major diseases; • Refine the IDM and IPM methods developed against major diseases, insect pests and vectors in light of new information from basic studies ; • Strengthen: methods for undertaking surveillance and monitoring on the emergence and dynamics of new and known pests and vectors; early-warning systems; and packages of management practices against the pests and vectors and • Strengthen awareness creation about integrated disease management through: developing and distributing simple handheld pocket guides; using multiple communication media; and advocacy for legislative support.
5.2.5 Irrigation water and nutrient management			
Inadequate packages of recommendations on: macro-, micro-, organic- and	• Fine tune the current fertilizer rates recommended for different agro-ecologies and production systems;	• Develop packages of recommendations on integrated soil fertility management practices appropriate for different agro-ecologies and	• Refine packages of recommendations on integrated soil fertility management practices appropriate for different agro-

inorganic- fertilizers appropriate for different production and processing scenarios; inadequate information on: water requirements, irrigation scheduling, and water-efficient irrigation systems appropriate for different agro-ecologies and soil types; and lack of information on critical water depletion levels for different varieties and developmental stages	• Determine new sources and rates of: organic and inorganic fertilizers to supply adequate amounts of both macro- and micro- nutrients required for production of high-quality potato in different agro-ecologies ; • Determine specific water and nutrient requirements and irrigation scheduling for different agro-ecologies and soil types; • Introduce and adapt water-efficient irrigation systems or technologies; • Initiate developing computer model-based irrigation regimes/ scheduling appropriate for different agro-ecologies and soil types and • Determine critical water depletion levels and crop-coefficients, Kc (which incorporate crop characteristics and averaged effects of evaporation from the soil) for different varieties and developmental stages.	production systems and quality targets; • Refine recommendations on new sources and rates of: organic and inorganic fertilizers to supply adequate amounts of both macro- and micro- nutrients required for production of high-quality potato in different agro-ecologies; • Strengthen and refine information on specific water and nutrient requirements and irrigation scheduling for different agro-ecologies and soil types; • Refine and develop water-efficient irrigation technologies appropriate for different production scenarios; • Develop, validate and map computer model-based irrigation regimes or scheduling appropriate for different agro-ecologies and soil types and • Update and expand the information on critical water depletion and crop coefficient.	ecologies and production systems and quality targets; • Refine recommendations on new sources and rates of: organic and inorganic fertilizers to supply adequate amounts of both macro- and micro- nutrients required for production of high-quality potato in different agro-ecologies; • Strengthen and refine information on specific water and nutrient requirements and irrigation scheduling for different agro-ecologies and soil types; • Refine and develop water-efficient irrigation technologies appropriate for different production scenarios; • Develop, validate and map computer model-based irrigation regimes/ scheduling appropriate for different agro-ecologies and soil types and • Update and expand the information on critical water depletion and crop coefficient.
5.2.6 Agricultural economics			
Inadequate information on: characterization and diagnosis of farming systems, value chains and market efficiencies; rate of technology adoption and diffusion and impact; and inadequate information on production economics	• Undertake characterization and diagnosis of farming systems incorporating potato ; • Conduct analysis of value-chains and determine market efficiencies in different potato-growing agro-ecologies ; • Develop systems of generating and communicating market information to different actors in the value chain ; • Undertake studies on: production economics	• Update the information on characterization and diagnosis of farming systems incorporating potato; • Conduct analysis of value-chains and determine market efficiencies in different potato-growing agro-ecologies ; • Update systems of generating and communicating market information to different actors in the value chain ;	• Update the information on characterization and diagnosis of farming systems incorporating potato ; • Conduct analysis of value-chains and determine market efficiencies in different potato-growing agro-ecologies ; • Update systems of generating and communicating market information to different actors in the value chain ;

	(cost-benefit), rate of adoption and impacts of potato technologies; • Generate information on policy and legislative issues, prepare policy brief and/or recommendation, discussion fora, and present to EIAR's top-management to be pursued at higher levels and • Establish stakeholders' platform and ensure participation of all actors in the value chain.	• Undertake studies on: production economics (cost-benefit), rate of adoption and impacts of potato technologies; • Generate information on policy and legislative issues, prepare policy brief and/or recommendation, discussion fora, and present to EIAR's top-management to be pursued at higher levels and • Strengthen stakeholders' platform and ensure participation of all actors in the value chain.	• Undertake studies on: production economics (cost-benefit), rate of adoption and impacts of potato technologies; • Generate information on policy and legislative issues, prepare policy brief and/or recommendation, discussion fora, and present to EIAR's top-management to be pursued at higher levels and • Strengthen stakeholders' platform and ensure participation of all actors in the value chain.
5.2.7 Agricultural extension and gender			
Lack of gender disaggregated information across the value chains; inadequate knowledge and skill on improved potato technologies across the production, processing, marketing and consumption continuum; and absence of easily accessible data base	• Characterize and mainstream gender roles and perspective in the processes of development and adoption of technologies; and production, marketing and utilization of potato; • Promote participatory technology development and promotion and • Create awareness and identify technology-cum-information dissemination and popularization methods enhancing production, processing and consumption of potato in both rural and urban areas (training, manuals, leaflets, etc., web-based digital repository, and international knowledge and technology banks).	• Characterize and mainstream gender roles and perspective in the processes of development and adoption of technologies; and production, marketing and utilization of potato; • Promote participatory technology development and promotion and • Create awareness and identify technology-cum-information dissemination and popularization methods enhancing production, processing and consumption of potato in both rural and urban areas (training, manuals, leaflets, etc., web-based digital repository, and international knowledge and technology banks).	• Characterize and mainstream gender roles and perspective in the processes of development and adoption of technologies; and production, marketing and utilization of potato; • Promote participatory technology development and promotion and • Create awareness and identify technology-cum-information dissemination and popularization methods enhancing production, processing and consumption of potato in both rural and urban areas (training, manuals, leaflets, etc., web-based digital repository, and international knowledge and technology banks).
5.2.8 Agricultural mechanization			
Lack of agricultural machinery, implements and equipment for pre- and post-	• Inventorize research-developed and locally available small-scale technologies, evaluate and promote those appropriate for pre- and post-	• Avail pre- and post-harvest mechanization technologies through adaptation to suit existing situations.	• Avail more advanced and appropriate pre- and post-harvest implements through adaptation to suit existing situations.

harvest operations	harvest management of potato(row planters, weeders, fertilizer-placers, cultivators, harvesters/lifters and graders); • Introduce and adapt agricultural mechanization technologies appropriate for small-scale farmers growing potato.		
5.2.9 Food science, postharvest management and value addition			
Inadequate information on nutritional and physicochemical characteristics of improved varieties, elite materials and the germplasm of potato; no technologies/ methods of semi- or full-processing, packaging and storing potato; and heavy post-harvest losses	• Generate information on physicochemical characteristics and processing-quality of improved varieties, elite materials and the available germplasm ; • Generate information on nutritional and anti-nutritional factors and profile of traditional potato-based staple foods ; • Develop methods and techniques of producing processed and value-added products of potato ; • Assess the causes and determine extent of postharvest losses across different production areas and market outlets and • Introduce and adapt post-harvest management technologies (harvesting, storage, handling, packaging, processing).	• Develop brand processing technologies (canned, fermented beverages, formulation of composite flour for weaning and therapeutic diets) for commercial purpose ; • Introduce and adapt small-scale semi-processing, processing and packaging equipment for food and non-food products.	• Introduce and adapt controlled atmosphere (temperature and humidity) storage techniques and technologies; • Develop brand processing technologies (canned, fermented beverages, formulation of composite flour for weaning and therapeutic diets) for commercial purpose and • Introduce and adapt small-scale semi-processing, processing and packaging equipment for food and non-food products.
5.2.10 GIS and Agro-meteorology			
Inadequate information on suitability mapping; and agro-climatology and crop modeling for potato production	• Conduct spatial suitability analyses and develop suitability map of potato across the various agro-ecologies; • Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall in meeting crop water requirements under rain-fed and irrigated systems;	• Refine and expand the suitability map; • Refine the modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall in meeting crop water requirements under rain-fed and irrigated systems and • Develop early warning and forecasting methods.	• Validate and refine suitability map; • Refine the modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall in meeting crop water requirements under rain-fed and irrigated systems and • Refine early warning and forecasting methods.

5.2.11 Capacity building			
Inadequate resources • Physical • Human • Finance	• Strengthen the number of research and technical staff through recruitment; • Improve technical cunning of the research staff through short- and long-term trainings tailored to upgrade research skills and qualifications; • Create favorable working environment (revising carrier structure, incentive mechanisms and reward external grant-winners) ; • Strengthen dexterity of researchers and technicians in application of specific topics through experience-sharing and study tours to places of excellence; • Furnish or Equip research centers with laboratories; offices; communication facilities; additional land for seed multiplication, trial and quarantine; and other research facilities; • Allocate sufficient budget for research and capacity building and improve efficiency of utilization and • Identify and organize research centers and sub-centers to assume the leading role to coordinate research on specific thematic area(s) of their competence.	• Strengthen the number, qualification and skill of the research and technical staff through recruitment, short- and long-term trainings and visits; • Create favorable working environment (revising carrier structure, incentive mechanisms and reward external grant-winners); • Strengthen the capacity of research centers with laboratories; offices; communication facilities; additional land for seed multiplication, trial and quarantine; and other research facilities; • Allocate sufficient budget for research and capacity building and improve efficiency of utilization and mobilize fund from external sources and • Strengthen research centers and sub-centers to assume the leading role to coordinate research on specific thematic area(s) of their competence.	• Strengthen the number, qualification and skill of the research and technical staff through recruitment, short- and long-term trainings and visits; • Create favorable working environment (revising carrier structure, incentive mechanisms and reward external grant-winners); • Strengthen the capacity of research centers with laboratories; offices; communication facilities; additional land for seed multiplication, trial and quarantine; and other research facilities; • Allocate sufficient budget for research and capacity building and improve efficiency of utilization and mobilize fund from external sources and • Strengthen research centers and sub-centers to assume the leading role to coordinate research on specific thematic area(s) of their competence.
5.2.12 crosscutting themes			
Gender	Organize gender disaggregated data for technology dissemination, adoption and impact of technologies; and in the course of technology demonstration, popularization, and training ensure that all female-headed households and at least 30% of beneficiaries to be women from male-headed households.		
Climate change	Develop research programs that would adequately address the challenge to increase resilience of vulnerable communities.		
Knowledge management	Consider modern facilities of ICT instrument in knowledge and information transfer and sharing processes.		

The Next Steps

Following the approval of the strategy by the top management of EIAR, it is essential to prepare the implementation plan, without which this strategy is not going to reach fruition. The implementation plan will be developed using a common Guideline adopted by the EIAR Planning, Monitoring and Evaluation Directo rate to provide guidance to research teams develop implementation plans. The implementation plan will thus come out as Volume II of the research strategy, which will serve as the blueprint to guide the National Potato Research for the next fifteen years (2016-2030). The major contents of the implementation plan will revolve, among others, around the following topics:

- Develop implementation plan;
- Develop monitoring and evaluation plan;
- Develop impact assessment plan and
- Develop reassessment plan for the strategy.

Root Crops Research Strategy

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Introduction

The root crops (sweet potato, cassava, taro, yam and anchote) are most important crops in south, south west, south east and north western parts of Ethiopia where a great number of households predominantly rely on as a source of food. Research on the various root and tuber crops has been going on since the establishment of the Institute of Agricultural Research (IAR) in 1966 under horticultural crops research division at different research centers and in higher learning institutions in a fragmented manner. In 1997, the root crops research was reorganized at national level to constitute three projects (Enset; potato and sweetpotato; and other root crops) respectively being coordinated by Areka, Holetta and Hawassa Research Centers. Sweet potato is now part of the root crops research program. Although a comprehensive root crops research, strategy was developed in the late 1990s during the tenure of EARO it was not implemented in its entirety due mainly to structural changes in the research system. In pursuit of delivering outputs matching national and sectoral economic drives; and aligned to the Government's development policy frameworks, EIAR is now impelled to develop a new research strategy for these crops. Accordingly, the National Root Crops Research Program has prepared this long-term research strategy (2016-2030); which was drafted by building on the experiences and lessons gained from the previous strategy that was followed through, sparsely as it was, over the last fifteen years. This new research strategy has been developed by a multi-disciplinary team of researchers working on root crops to: serve as the central document guiding their efforts for the next 15 years; and provide an all-inclusive framework for prioritizing and coordinating research activities towards the achievement of shared- vision and objectives.

The strategy is organized in six major chapters whereby this background section together with descriptions of the rationale, vision, mission, goal and objectives constitute the introductory chapter 1. Chapter 2 provides an overview of the importance of root crops in the Ethiopian agriculture; and food and nutrition security. Chapter 3 briefly discusses the situation analysis undertaken by assessing the internal environment as well as the external one involving all the key stakeholders to capture their reflections, concerns and desires. In chapter 4 what ? are presented the critical issues that have been sifted out from the situation analysis and articulated as key challenges facing the program. Chapter 5 discusses the actual strategic interventions to be pursued under the various thematic areas of the research to tackle the critical issues identified. Chapter 6 provides key elements of follow up documents that need to be worked out in the next steps as they are prerequisites for effective implementation of the strategy.

Rationale

Lessons learned over the last several years indicate that judicious dissemination and application of proven technologies and inputs will bring about significant and positive changes in both the production and productivity of root crops and the wellbeing of the producers.

Cognizant of the available physiographic and climatic settings suitable for root crops production coupled with conducive policy and regulatory frameworks put in place, the crops can play a key role to: ensure food and nutrition security for millions of small-scale farming households; strengthen the opportunity for job creation and income generation; foster expansion of agro-industries, agri-business and import substitution; diversify the base for foreign earnings; and stabilize the macro-economy in general.

Therefore, the need for maximizing utilization of potential agro-climatic, physiographic and hydrologic conditions of the country to increase production, productivity and marketability of root crops is a matter of urgency. In the present context it is not only to widen the gap between what is available at research level and how much of that is being used by the farmer; but also are little the results attained thus far by the research system in comparison with the potential that could be realized from the crops. In order to create a condition where these divergent scenarios could converge and thus the commodities' potential could best be exploited, it is absolutely necessary to develop a well-defined and an all-inclusive research strategy representing and addressing the interests of all the key stakeholders involved in the value chains of root crops. Such a strategy creates a stronger cohesion and partnership among stakeholders and serves as a roadmap to: guide the research program planning and implementation in line with the objectives and targets of GTP-II and that of EIAR; records of accomplishment of results and lessons; and mobilize resources from national and/or international sources. It is with this rationale that the National Root Crops Research Program (NRCRP) - Team has developed this Research Strategy to achieve a common vision and objectives.

The NRCRP -Team has a strong conviction that a thriving future for the commodities can be achieved only if it involves meaningful collaborations between farmers, input suppliers, exporters, actors in agribusiness and agro-industry, traders, technicians, scientists, and others engaged in the value chains. To this end, the research team has formulated a set of principles and values that reflect its vision, mission, goal and objectives underpinning its commitments and desires as indicated below.

Vision

The vision of the National Root Crops Research Program (NRCRP) is to be a competent research program availing technological innovations and knowledge that can significantly contribute to improved livelihoods and provision of competitive products for manufacturing industries and export market

Mission

The mission of the NRCRP is to conduct agro-ecology- and product- based research, generate, adapt and transfer technologies and knowledge that are acceptable by users for improving productivity, nutritional quality and sustainable development of agriculture, agribusiness and export market

Goal

The goal of the NRCRP is to contribute to the EIAR's role towards the achievement of the sectorial objectives of ensuring food security, sustainable delivering of raw materials for agro-industries and import substitution, expanding the bases for the country to gain foreign earnings from agricultural exports, and (iv) increasing livelihood resiliency and environmental sustainability while reducing vulnerability to climate change

Objectives

The overall objective of the NRCRP is to increase the production, productivity, quality and versatility of root crops through multidisciplinary and participatory research approach leading to their increased share in the national economy and advancement. Specific objects of the program, among others, include the following:

- To generate and adapt technologies that can sustainably enhance productivity and quality of root crops to leverage their role in the food security, provide sustainable raw materials for manufacturing firms, import substitution and hard currency earnings;
- To collect, characterize and conserve the genetic resources of root crops for research use;
- To generate information on socio-economic aspects of root crops with regard to consumption, production and marketing and
- To generate technologies that provides competitive products for micro-processing businesses and creates jobs for rural and urban women and youth.

Importance of Root Crops

Production and utilization of root crops in Ethiopia dates back 3000 years ago with domestication of such indigenous root crops as "Ethiopian dinich", yam and Anchote; while production and utilization of introduced-root crops such as Irish and sweet potatoes and cassava elapsed only several hundred years; but are serving as staple food in a much wider areas of the country. Root crops are grown over a broad range of environments of mountain slopes (anchote and Ethiopian dinich*)* to zero meters above sea level (cassava). Sweetpotato is essentially a warm weather crop while cassava is both a tropical and subtropical drought tolerant crop. Taro is essentially a

lowland crop partly because of its temperature sensitivity. Yam grows well in hot areas with temperatures between 25-30^{0}C and well distributed rainy days of 7-10 months. Anchote seems to have a wider ecological adaptation as it grows well in lowland, mid-land and highland areas. There are four major cropping seasons for root crops: the first and most frequently used is the Belg-season; the second is the Meher-season where farmers grow mainly for multiplication of planting materials; the third one is the residual system which is very common for the production of yam and sweetpotato where the residual moisture conserved during the main rainy season is utilized; and the forth system is by using irrigation mainly to produce planting materials and producing taro around water sources.

Root crops are rich sources of carbohydrate, starch, sugar, fiber and minerals such as calcium, magnesium, potassium, zinc and iron. They are also good sources of vitamins such as vitamins A (especially from orange-fleshed sweetpotato), B complex, C and E. Root crops cover around 1.5% of the area under crops and contribute for six percent of crop production in the country. As climate change is increasing becoming a threat to the production of cereal crops, the importance of root crops is expected to increase; as root crops are considered good emergency crops during failure of other crops due to climatic factors such as drought. They are the major source of food security for more than four million households representing ca. 22 million people in the south, south western and eastern parts of the country. Root crops can have a great potential to substitute import in the textile, pharmaceutical, soft drink, beer and ethanol/alcohol industries as they can provide a wide array of products of industrial uses.

Situation Analysis

Two categories of forces and factors influencing the conception, formulation, action and implementation of the strategy were analyzed as external and internal factors. The external factors (influences that are outside the research system) represent both the interests of stakeholders that the research should serve and the potential role that they can play to complement or synergize the research. Specific situations or stakeholders' interests that hold back research stride or the research falls short to positively respond to, represent the challenges (C); while those that create motivation for the research represent the opportunities (O). Therefore, the situation analysis of the external factors essentially examined Opportunities and Challenges (OC) presented from the existing Political /Policy /Legal, Economic, Educational, Socio-cultural, Technological/ Technical, and Environmental (PEST) perspectives of the factors. Almost all key stakeholders, notably the Ministries of: Agriculture and Natural Resources, Trade and Industries; exporters; private industries; farmers' unions; various relevant technical units of EIAR; the Regional Research Institutes and centers; and Higher Learning Institutions involved in root crops research have taken part in the process.

Analysis of the internal situation (influences that are outside the research system) was made by scrupulously examining whether or not there is the capacity within the research system that can readily be deployed by the team to deliver outputs or promptly respond to stakeholders' quests or challenges. While the presence of such a capacity denotes the strength (S) of the team; the capacity which is required to deliver desirable outputs but falls short to exist represents the weakness (W). Therefore, analysis of the situation of internal factors examined Strengths and Weaknesses (SW) of the research team in terms of the existing resources (human, physical and fiscal); inter- and intra- disciplinary integrations, complementarities and synergies; availability of technologies, information and knowledge; and organization of internal system, and geographic coverage of the research program.

The results from the situation analysis were finally consolidated in a form of metrix whereby prevailing strengths, weaknesses, opportunities, and challenges (SWOC) were narrated with respect to their relevance to the various thematic areas that the research team is engaged in. From the situations narrated as such then were formulated the issues that the research system needs to address in the short-, medium-, and long- term plans. Experiences of other countries with respect to the level they have reached in research and development aspects of root crops were also examined to set a benchmark for the strategy.

Strategic Issues

The major strategic thematic areas identified for the Root Crops Research Program include: Genetics and breeding; Crop protection; Agronomy and physiology; Irrigation water and nutrient management; GIS and Agro-meteorology; Technology multiplication and seed research; Agricultural economics; Agricultural research extension and gender; Agricultural mechanization; Food science, postharvest management and value addition; Capacity building; and Additional cross-cutting themes. Specific strategic issues pertaining to each thematic area are presented under Table 1.

Table .1 Strategic issues facing the National Root Crops Research Program and their relevance in the short-, medium- and long- terms

Thematic area	**Strategic issue**	Relevance in the		
		Short-term (1-5 years)	Medium-term (6-10 years)	Long-term (10-15 years)
Genetics and breeding	• Lack of early-maturing varieties; • Limited number of varieties that meet farmers' preferences in terms of quality traits such as dry matter, β-carotene and hydrogen cyanide (HCN) contents; • Limited number of varieties suitable for stress areas and marginal environments • Lack of varieties to be used as raw material for targeted purposes such as processing of starch, flour, chips, • Lack of dual-purpose varieties of root crops that can also be used as leafy vegetables; • Inadequate utilization of the potential use of modern biotechnological tools in breeding and • Inadequate engagement in breeding for improving nutritional quality of root crops (e.g. micronutrients).	x	x	x
Crop protection	Pathology • Limited periodic survey and surveillance on diseases of root crops; • Inadequate results on identification of sources of resistance to diseases and specific races/pathotypes; • Inadequate utilization of the potential use of modern biotechnological tools to identify sources of disease resistance; • Inadequate options of integrated disease management (IDM) practices suitable for different agro-ecologies and production systems and • Inadequate utilization of the potential use of GIS for disease mapping Entomology • Limited periodic survey and surveillance on existing and newly emerging insect pests of root and tuber crops; • Inadequate results on identification of sources of resistance to major insect pests of root crops; • Inadequate options of integrated pest management (IPM) practices suitable for different agro-ecologies and production systems; • Inadequate information on efficacy of bio-pesticides used against insect pests of root crops; • Lack of information on storage pests and their management options • Inadequate research on botanicals for the control of major insect pests of root crops; Weed Science	x	x	x

	• Limited periodic survey and surveillance on weed flora incidence and abundance; • Inadequate information on biology of weeds and their competition effects on root crops; • Inadequate information on the effects of climate change on weed dynamics and associated losses of root crops; • Inadequate options of integrated weed management (IWM) practices suitable for different agro-ecologies and production systems and • Inadequate utilization of the potential use of GIS for mapping distributions of weeds			
Agronomy and physiology	• Lack of packages of agronomic recommendations specific to agro-ecologies and/or production systems; • Inadequate agronomic recommendations appropriate for marginal environments; • Lack of packages of agronomic recommendations on integrated nutrient management practices for different agro-ecologies; • Little/no information on micro-nutrient requirement and utilization; • Inadequate information on appropriate rate of organic fertilizers (compost, manures) and • Limited information on crop physiology and modeling	x	x	x
Irrigation water and nutrient management	• Inadequate packages of recommendations on crop-water requirements and irrigation scheduling appropriate for producing root crops under small- and large- scale irrigation conditions • Lack of data base on the available and/or potential irrigation schemes as to their suitability for production of root crops;	x	x	x
GIS and Agro-meteorology	• Lack of GIS-based information and knowledge applicable for timely operation of farm practices optimizing use of scarce resources; • Inadequate information on suitability map of the different agro-ecologies for root crops production	x	x	x
Technology multiplication and seed research	• Lack of focus/interest by seed enterprises to engage in multiplication of planting material of root crops; • Shortage of planting material of early-generations (pre-basic and basic seed levels) of root crops with sufficient quantity and quality; • Limited technical support given to farmers, seed-grower cooperatives and private seed producers; • Lack of recommendations on storage systems that enable to maintain quality of planting material; • Lack of awareness about/ emphasis to the importance of using planting material that are strictly free from diseases and pests	x	x	x

Agricultural economics	• Limited information on characterization and diagnostics of farming systems in different agro-ecologies involving root crops; • Limited information on adoption and impact of technologies on root crops; • Inadequate information on value chains, marketing and market efficiencies of root crops	x	x	x
Agricultural extension and gender	• Inadequate course of action of demonstration and popularization hastening the uptake of improved technologies as well as forward- and backward- flow of information/feedback; • Limited stance of gender mainstreaming in the processes of development and adoption of technologies; and production, marketing and utilization of root crops	x	x	x
Agricultural mechanization	• Lack of mechanization technologies for pre- and post-harvest operations (such as row planters, harvesters and storage facilities) appropriate for smallholder farmers; • Limited supply of prototypes of even the little number and type of pre- and post- harvest machineries at hand for their wider multiplication and distribution; • Inadequate information on efficiencies of pre- and post- harvest machineries at hand; • Lack of participatory processes involving farmers and experts as well in the course of developing and evaluating farm equipment before the technologies are multiplied and distributed	x	x	x
Food science, postharvest management and value addition	• Lack of recommendations on storage methods increasing the shelf life of products of root crops; • Inadequate information on nutritional qualities and anti-nutritional contents of root crops; including compositions of macro and micro nutrients; • Lack of technologies/methods for fortification and/or root crops-based alternative food products	x	x	x
Capacity building	Inadequate resources • Physical • Human • Finance	x	x	x
Additional crosscutting themes	• Climate change and knowledge management	x	x	x

Note the mark "X" denotes that the issue is relevant and needs to be tackled

Research Themes and Strategic Interventions

Most of the research issues identified to be addressed by the root crops research team are multi-institutional, multi-thematic, multidisciplinary, participatory, and need to be implemented in collaboration with farmers, extensionists and a wide range of other partners to be involved in the whole spectrum of the value chains. The research themes are built on the disciplinary as well as crosscutting themes briefly discussed hereunder. The strategic interventions proposed to tackle each of the issues identified for each theme, and need to be implemented during the next fifteen years on the: short-, medium- and long- term basis, are presented in Table 2 following the narrations of the disciplinary and cross-cutting thematic areas.

Research Themes

Genetics and breeding

In the years ahead, the root crops sub-sector foresees a steady demand for varieties with higher and more stable yields and acceptable quality. To keep pace with this demand, much of the focus will be on developing new varieties that are high yielding, adapted to a variety of environments, and resilient in the face of multiple stresses such as climate change, emergence of new pests and diseases, and other biotic and abiotic factors. The strategy will generally seek to accelerate crop improvement by using both conventional and modern methods and technologies that make possible handling of large volumes of genetic material and select with greater precision. This will involve stronger integration of conventional plant breeding approaches with modern tools and methods of biotechnology.

Crop protection

To make crop production more eco-efficient is to achieve yield stability and reduce the chances of crop failure due to diseases and other pests, whose dynamics are shifting as a result of climate change. To this end, the research will focus on both host plant resistance and biological control with greater emphasis to integrated approaches of controlling diseases, insect pests, weeds and vertebrate pests through Integrated Pest Management (IPM) systems.

Agronomy and physiology

Keeping the principle of eco-efficiency, the agronomy and crop physiology endeavor will focus towards developing improved crop management practices specifically tailored for particular growing conditions and thus open the way for optimal expression of genetic potential of varieties and enhancing the physiological and agronomic efficiencies of the crops.

Irrigation water and nutrient management

Development of water-efficient management practices including micro-irrigation, fertigation; irrigation scheduling, etc. constitute arrears of intervention related to production of root crops as they are best fitting for production under irrigation conditions.

GIS and agro-meteorology

In formulating strategic interventions to be harnessed for achieving the objectives stipulated from the outset, it will be given due attention to GIS and agro-meteorology for better understanding of the dimensions of local climate and farming systems (physical climate, social, economic, farming systems, etc.) for targeting and developing the right technology for the right environment.

Technology multiplication and seed research

The core of research activities envisioned by the technology multiplication and seed research component of the strategy will be to: identify key problems associated with producing sufficient quantity and quality of initial material by generating basic information that would help to develop technologies addressing the challenges; adopt advanced tools for developing disease-free planting material; identify and adopt good practices of technology multiplication for large-scale production; and devise an internal system whereby expeditious multiplication of high-quality planting material would be effected in order to meet ever growing demands.

Agricultural economics

Agricultural economics is among the core themes of research as it plays a vanguard role in linking the biological sphere of the research and the economic validity of the results when actually being implemented by the farmer or other targets in the recommendation domains. Furthermore, it has also a key role to play in addressing policy issues that are instrumental in developing and promoting efficient, functional and sustainable value chains of root crops.

Agricultural extension and gender

The agricultural extension and gender component of the research brings in stakeholders together to formulate relevant research agenda as it does also take out promising research results to the demonstration and extension processes. Notwithstanding the role the extension component plays in addressing the social aspects of the research, it is the main channel for the two-way flow of information between the research system on one hand and the end users of the research results on the other. Therefore, addressing issues related to socio-economic and research extension in the strategy is vital to attain the successes that the research team envisages. It will also be crucial to address

issues related to gender equality and inclusiveness of the research process in general through this component.

Agricultural mechanization

The main challenges associated with agricultural machinery and post-harvest handling is the fact that producers in Ethiopia had little opportunity to employ small-scale farm implements, water pumps for irrigation, means of transportation, and storage structures that are appropriate for root crops. Both pre- and post- harvest operations are done manually using age-old traditional methods. Losses in both quantities and qualities associated with these manual and dated practices are often appalling. It is therefore, imperative to consider this field of research in this research strategy.

Food science, postharvest management and value addition

As root crops have a great deal of potential in the food industry, it is essential to work on chemical characterization and profiling of the available varietes and eventually the genepool for nutritional as well as industrial values. It is also critical to develop recommendations on post-harvest technologies that would improve shelf life of the produce. Establishing alternative ways of processing the produce in view of increasing their shelf life will also open up a new vista of value addition and product diversification and thus better market opportunities for producers and options of choices for consumers.

Capacity building

Two important issues were identified under this topic: the need for strengthening the capacity of the research team; and the stakeholders involved in the value chains in general need to have a strong, functional, influential and sustainable forum that will shape up the future of the research, production, processing, trade, and consumption of the commodities.

Crosscutting themes

Gender: The role of women in the agricultural system is critical as women contribute 70 percent of farm labour at harvesting and in post-harvest activities. But women farmers have only limited access to resources, services, land and credit. Unequal gender relations often make women more vulnerable to the effects of poverty, land degradation, and climate change. If the gender gap were eliminated, FAO asserts that total agricultural output would increase. Cognizant of this, the strategy upholds integration of gender concerns into research objectives, technology development, extension, and evaluation frameworks.

Climate change: In Ethiopia, climate change is already having an impact on the livelihoods of different communities in different corners of the country. Therefore, the research strategy will place due considerations to availing technologies that would help actors in the value chains to respond to climate change through adaptation and/or mitigation approaches.

Knowledge management (KM): Through KM interventions aided by new information technologies, it is possible to help improve smallholders' access to resources that help them improve their farm productivity and competitive ability. KM will also help to create research products in a more collaborative manner that makes them more suitable for diverse audiences. For this purpose, the research team will make results more readily available by spearheading formations of multi-stakeholder platforms that facilitate interaction and promote learning for change, mentoring, and networking.

Strategic Interventions

Table 2 Strategic interventions planned to address critical issues facing the National Root Crops Research Program in the short-, medium- and long- terms

Thematic areas	Strategic Interventions		
	Short term (5 years)	**Medium term (10 years)**	**Long term (15 years)**
5.2.1 Genetics and breeding			
Lack of varieties with: early-maturity, quality traits of farmers' preferences, adaptability to stress environments, suitability as raw material for processing and dual-use for root and leaf; inadequate use of: modern biotechnological tools and breeding for improving nutritional quality	• Screen local collections and identify early-maturing genotypes to use them for: direct development of varieties or gene sources to transfer earliness onto established varieties, elite materials or other breeding entries to be developed into new varieties; • Introduce, adapt and register early-maturing varieties suitable for the local growing conditions; • Identify, characterize, delineate, map and document major environments considered to be marginal for production of root crops; • Screen local collections and identify accessions that can be used to develop varieties suitable for marginal environments; • Introduce, adapt and register varieties suitable for marginal environments; • Screen local collections and identify genotypes with desirable characteristics of starch, suitability for leaf consumption and other traits; • Introduce, adapt and register varieties suitable for industrial processing and leaf consumption; • Undertake chemical characterization and	• Broaden the genetic bases of sweetpotato, cassava and yam through planned and extensive hybridization programs targeted for: earliness, adaptability to marginal environments, high starch content and transfer of other desirable traits; • Broaden the genetic bases of root crops through planned and extensive hybridization programs targeted for high- dry matter, β-carotene, Fe and Zn, and low-HCN contents; • Strengthen the source of genetic variability for: earliness, adaptation to marginal environments, industrial processing and dual-purposes of root and leaf consumption through rigorous and effective screening and selection of both local and introduced germplasm material ; • Strengthen the source of genetic variability for high- dry matter, β-carotene, Fe and Zn, and low-HCN contents through rigorous and effective screening and selection of both local and introduced germplasm material; • Develop root crop varieties which in addition to high-yielding are tailored for: earliness, adaptation to marginal environments, industrial processing and dual-purposes of root and leaf consumption;	• Broaden the genetic bases of sweetpotato, cassava and yam through planned and extensive hybridization programs targeted for: earliness, adaptability to marginal environments, high starch content and transfer of other desirable traits; • Broaden the genetic bases of root crops through planned and extensive hybridization programs targeted for high- dry matter, β-carotene, Fe and Zn, and low-HCN contents; • Strengthen the source of genetic variability for: earliness, adaptation to marginal environments, industrial processing and dual-purposes of root and leaf consumption through rigorous and effective screening and selection of both local and introduced germplasm material ; • Strengthen the source of genetic variability for high- dry matter, β-carotene, Fe and Zn, and low-HCN contents through rigorous

	profiling of released varieties, and elite or germplasm materials of root crops using modern biotechnological tools; • Introduce, adapt and register varieties with high- dry matter and β-carotene and low-HCN contents; • Initiate screening of local germplasm material for high- dry matter, β-carotene, Fe and Zn, and low-HCN contents and • Maintain and produce, at suitable research centers/sites, sufficient quantity and quality of breeder seeds of released varieties of root crops.	• Develop root crop varieties with high- dry matter, β-carotene, Fe and Zn, and low-HCN contents; • Strengthen chemical characterization and profiling of released varieties, and elite or germplasm materials of root crops using modern biotechnological tools; • Carry out studies on genotyping and mapping of resistances of selected root crops to major disease and insect pests and • Maintain and produce, at suitable research centers/sites, sufficient quantity and quality of breeder seeds of released varieties of root crops.	and effective screening and selection of both local and introduced germplasm material; • Develop root crop varieties which in addition to high-yielding are tailored for: earliness, adaptation to marginal environments, industrial processing and dual-purposes of root and leaf consumption; • Develop root crop varieties with high- dry matter, β-carotene, Fe and Zn, and low-HCN contents; • Strengthen chemical characterization and profiling of released varieties, and elite or germplasm materials of root crops using modern biotechnological tools; • Strengthen and refine studies on genotyping and mapping of resistances of root crops to major disease and insect pests and • Maintain and produce, at suitable research centers/sites, sufficient quantity and quality of breeder seeds of released varieties of root crops.
5.2.2 Crop protection			
• Pathology • Limited survey and surveillance on diseases; inadequate: sources of resistance; use of biotechnological tools to identify sources of	Pathology • Undertake periodic disease surveys sufficiently covering the major areas and seasons where/in which root crops are produced ; • Conduct postharvest disease surveys and	Pathology • Undertake periodic disease surveys sufficiently covering the major areas and seasons where/in which root crops are produced and establish dynamic changes encountered over time;	Pathology • Undertake periodic disease surveys sufficiently covering the major areas and seasons where/in which root crops are produced and establish dynamic

resistance; options of IDM practices; and use of GIS for disease mapping; • • Entomology • Limited survey and surveillance on existing and newly emerging insect pests; inadequate: sources of resistance; options of IPM practices; and information on efficacy of bio-pesticides, storage pests and their management, and botanicals and • • Weed Science • Limited survey and surveillance on weed flora; inadequate information on: biology and competition effects of weeds, effects of climate change on weed dynamics and associated losses, options of IWM practices, and use of GIS for mapping weed distributions .	determine the causes and extent of quantitative and qualitative losses of root crops across different production areas and seasons; • Identify virulent races of pathogens causing major diseases in root crops ; • Identify genetic sources of resistance, against major diseases, to be used for: direct development of varieties or transfer of resistance-genes onto established varieties and elite or other materials in the breeding program; • Undertake characterization and profiling of released varieties, and elite or germplasm materials of root crops with respect to their resistance to major diseases using modern biotechnological tools and • Develop options of effective integrated disease management (IDM) practices appropriate for different agro-ecologies and production systems. Entomology • Undertake periodic surveys on insect pests sufficiently covering the major areas and seasons where/in which root crops are produced; • Conduct postharvest surveys on insect pests, identify major storage pests and determine the causes and extent of quantitative and qualitative postharvest losses of root crops across different production areas and seasons ; • Undertake extensive screening of landraces of root crops and identify genotypes with resistance against such	• Conduct postharvest disease surveys and determine the causes and extent of quantitative and qualitative losses of root crops across different production areas and seasons; and establish dynamic changes encountered over time; • Strengthen identification of virulent races of pathogens causing major diseases in root crops ; • Develop varieties in which resistance genes from identified sources were introgressed; and also strengthen identification of new sources of resistance ; • Strengthen characterization and profiling of released varieties, and elite or germplasm materials of root crops with respect to their resistance to major diseases using modern biotechnological tools and • Develop options of effective integrated disease management (IDM) practices appropriate for different agro-ecologies and production systems. Entomology • Undertake periodic surveys on insect pests sufficiently covering the major areas and seasons where/in which root crops are produced; and establish dynamic changes encountered over time; • Conduct postharvest surveys on insect pests, identify major storage pests and determine the causes and extent of quantitative and qualitative postharvest losses of root crops across different production areas and seasons; Undertake periodic surveys on insect pests sufficiently covering the major areas and	changes encountered over time; • Conduct postharvest disease surveys and determine the causes and extent of quantitative and qualitative losses of root crops across different production areas and seasons; and establish dynamic changes encountered over time; • Refine identification of virulent races of pathogens causing major diseases in root crops ; • Develop new varieties in which resistance genes from identified sources were introgressed; and also strengthen identification of new sources of resistance; • Strengthen and refine characterization and profiling of released varieties, and elite or germplasm materials of root crops with respect to their resistance to major diseases using modern biotechnological tools and • Develop options of effective integrated disease management (IDM) practices appropriate for different agro-ecologies and production systems. Entomology • Undertake periodic surveys on insect pests sufficiently covering the major areas and seasons where/in which root crops are produced; and establish dynamic

	major pests as sweetpotato- weevil and butterfly; cassava-scale insect; and others; • Introduce and evaluate clones from exotic sources for resistance to major insect pests of root crops; • Develop options of effective integrated pest management (IPM) practices appropriate for different agro-ecologies and production systems and • Establish facts on identification and efficacies of: biological enemies, bio-pesticides, and botanicals; and develop packages of recommendations to control insect pests using these options. Weed Science • Establish basic knowledge and information on identity, abundance, biology, ecology and dynamics of the weed flora in root crops-growing agro-ecologies and production systems; • Establish competition effects of grass and broad-leaf weeds on quantitative as well as qualitative losses of root crops across agro-ecologies and production systems; • Develop options of effective integrated weed management (IWM) practices appropriate for different agro-ecologies and production systems; • Undertake studies on the impact of climate change on weed dynamics and its implicit effects on root crops production and • Establish GIS-based mapping of the identity and abundance of the weed flora	seasons where/in which root crops are produced; and establish dynamic changes encountered over time ; • Undertake extensive screening of new landraces of root crops and identify genotypes with resistance against such major pests as sweetpotato- weevil and butterfly; cassava-scale insect; and others ; • Introduce and evaluate new clones from exotic sources for resistance to major insect pests of root crops; • Develop options of effective integrated pest management (IPM) practices appropriate for different agro-ecologies and production systems; • Establish facts on identification and efficacies of new: biological enemies, bio-pesticides, and botanicals; and develop packages of recommendations to control insect pests using these options Weed Science; • Strengthen the basic knowledge and information on identity, abundance, biology, ecology and dynamics of the weed flora in root crops-growing agro-ecologies and production systems ; • Strengthen the information on competition effects of grass and broad-leaf weeds on quantitative as well as qualitative losses of root crops across agro-ecologies and production systems; • Develop options of effective integrated weed management (IWM) practices appropriate for different agro-ecologies and production systems ;	changes encountered over time; • Conduct postharvest surveys on insect pests, identify major storage pests and determine the causes and extent of quantitative and qualitative postharvest losses of root crops across different production areas and seasons; Undertake periodic surveys on insect pests sufficiently covering the major areas and seasons where/in which root crops are produced; and establish dynamic changes encountered over time ; • Undertake extensive screening of new landraces of root crops and identify genotypes with resistance against such major pests as sweetpotato- weevil and butterfly; cassava-scale insect; and others ; • Introduce and evaluate new clones from exotic sources for resistance to major insect pests of root crops; • Develop options of effective integrated pest management (IPM) practices appropriate for different agro-ecologies and production systems ; • Establish facts on identification and efficacies of new: biological enemies, bio-pesticides, and botanicals; and develop packages of recommendations to control insect pests using these options. Weed Science

	in root crops-growing agro-ecologies and production systems.	• Strengthen studies on the impact of climate change on weed dynamics and its implicit effects on root crops production and • Refine the information on GIS-based mapping of the identity and abundance of the weed flora in root crops-growing agro-ecologies and production systems.	• Strengthen and refine the basic knowledge and information on identity, abundance, biology, ecology and dynamics of the weed flora in root crops-growing agro-ecologies and production systems ; • Refine the information on competition effects of grass and broad-leaf weeds on quantitative as well as qualitative losses of root crops across agro-ecologies and production systems; • Develop options of effective integrated weed management (IWM) practices appropriate for different agro-ecologies and production systems and • Refine the information on the impact of climate change on weed dynamics and its implicit effects on root crops production; and on GIS-based mapping of the identity and abundance of the weed flora in root crops-growing agro-ecologies and production systems.
5.2.3 Agronomy and physiology			
Lack of specific agronomic recommendations for: different agro-ecologies and systems, marginal environments, and integrated nutrient management; little/no information on: micronutrient	• Develop appropriate packages of agronomic recommendations (planting time and density/spacing, rate of application of organic and inorganic fertilizers, etc.) specific to agro-ecologies and production systems ; • Develop packages of agronomic recommendations appropriate for acidic	• Fine tune packages of agronomic recommendations (planting time and density/spacing, rate of application of organic and inorganic fertilizers, etc.) specific to agro-ecologies and production systems; • Strengthen and update packages of agronomic recommendations appropriate for acidic soils, and low-moisture and waterlogged areas;	• Fine tune packages of agronomic recommendations (planting time and density/spacing, rate of application of organic and inorganic fertilizers, etc.) specific to agro-ecologies and production systems; • Strengthen and update packages

utilization and crop physiology and modeling.	soils, and low-moisture and waterlogged areas; • Develop packages of recommendations on integrated nutrient management practices including micronutrients appropriate for root crops; • Undertake systematic studies on crop physiology and generate information useful to enhance: plant efficiencies of water use, photosynthesis, and nutrient use; and crop growth and development and • Develop crop-modeling tools that can be employed to forecast short- and long-term local climate patterns in, and determine effects of climate change on root crops production systems.	• Refine packages of recommendations on integrated nutrient management practices including micronutrients appropriate for root crops; • Undertake systematic studies on crop physiology and generate information useful to enhance: plant efficiencies of water use, photosynthesis, and nutrient use; and crop growth and development and • Refine crop modeling tools that can be employed to forecast short- and long- term local climate patterns in, and also determine effects of climate change on root crops production systems.	of agronomic recommendations appropriate for acidic soils, and low-moisture and waterlogged areas; • Refine packages of recommendations on integrated nutrient management practices including micronutrients appropriate for root crops; • Undertake systematic studies on crop physiology and generate information useful to enhance: plant efficiencies of water use, photosynthesis, and nutrient use; and crop growth and development and • Refine crop modeling tools that can be employed to forecast short- and long- term local climate patterns in, and also determine effects of climate change on root crops production systems.
5.2.4 Irrigation water and nutrient management			
Inadequate packages of recommendations on crop-water requirements and irrigation scheduling; and lack of data base on the available and/or potential irrigation schemes.	• Determine specific water requirements of root crops under different agro-ecologies and develop appropriate irrigation schedules; • Identify and map the existing irrigation schemes with respect to their suitability for production of root crops ;	• Refine and strengthen information on water requirements of root crops under different agro-ecologies and develop appropriate irrigation schedules • Develop water-efficient irrigation systems/ technologies (drip irrigation) and fertigation scheduling appropriate for cultivation of root crops in different agro-ecologies	• Refine and strengthen information on water requirements of root crops under different agro-ecologies and develop appropriate irrigation schedules • Refine and strengthen development of water-efficient irrigation systems/ technologies (drip irrigation) and fertigation scheduling appropriate for cultivation of root crops in different agro-ecologies

5.2.5 GIS and Agro-meteorology			
Lack of GIS-based information and knowledge for: timely operation of farm practices and suitability map	• Conduct spatial suitability analyses and develop suitability map of root crops as distributed across the various AEZs; • Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall and irrigation water requirements for production of root crops under irrigated and rain-fed conditions across different agro-ecologies.	• Refine information on modeling that can be employed to forecast local climate patterns in terms of seasonality of rainfall and irrigation water requirements for production of root crops under irrigated and rain-fed conditions across different agro-ecologies; • Develop integrated management practices fostering crop adaptation to climate change.	• Refine information on modeling that can be employed to forecast local climate patterns in terms of seasonality of rainfall and irrigation water requirements for production of root crops under irrigated and rain-fed conditions across different agro-ecologies; • Develop integrated management practices fostering crop adaptation to climate change.
5.2.6 Technology multiplication and seed research			
Lack of involvement of seed enterprises; shortage of planting material of early-generations; limited technical support to farmers and seed-growers; lack of recommendations on storage systems and awareness about the importance of disease- and pest- free planting material .	• Create awareness among seed-producing public and private enterprises and other stakeholders on the importance and business potential of producing good-quality planting materials of root crops using different formal and informal media of information-dissemination such as: workshops, discussion fora, field days, mass media, information leaflets and booklets, etc.; • Create awareness among farmers and extension experts and development agents (DAs) on the importance of using planting materials of root crops that are free from diseases and insect pests; and provide intensive trainings; • Produce and provide, to formal and/or informal seed-growers, sufficient amount of initial materials of early-generation seeds ; • Employ modern techniques and tools of biotechnology and tissue culture to identify and produce disease-free planting	• Keep creating awareness among seed-producing public and private enterprises and other stakeholders on the importance and business potential of producing good-quality planting materials of root crops using different formal and informal media of information-dissemination such as: workshops, discussion fora, field days, mass media, information leaflets and booklets, etc.; • Keep creating awareness among farmers and extension experts and development agents (DAs) on the importance of using planting materials of root crops that are free from diseases and insect pests; and provide intensive trainings; • Produce and provide, to formal and/or informal seed-growers, sufficient amount of initial materials of early-generation seeds; • Employ modern techniques and tools of biotechnology and tissue culture to identify and produce disease-free planting materials and • Strengthen information on storage systems appropriate for maintaining good-quality	• Keep creating awareness among seed-producing public and private enterprises and other stakeholders on the importance and business potential of producing good-quality planting materials of root crops using different formal and informal media of information-dissemination such as: workshops, discussion fora, field days, mass media, information leaflets and booklets, etc.; • Keep creating awareness among farmers and extension experts and development agents (DAs) on the importance of using planting materials of root crops that are free from diseases and insect pests; and provide intensive trainings; • Produce and provide, to formal and/or informal seed-growers,

	materials and • Establish storage systems appropriate for maintaining good-quality standards of planting materials of root crops.	standards of planting materials of root crops.	sufficient amount of initial materials of early-generation seeds; • Employ modern techniques and tools of biotechnology and tissue culture to identify and produce disease-free planting materials and • Refine and fine-tune recommendations on storage systems appropriate for maintaining good-quality standards of planting materials of root crops.
5.2.7 Agricultural economics			
Limited information on: characterization and diagnostics of farming systems; adoption and impact of technologies; and value chains, marketing and market efficiencies	• Undertake characterization and diagnosis of the farming systems involving root crops and document the socio-economic and cultural values and constraints; • Undertake studies on the rate of adoption and impacts of improved technologies of root crops; • Conduct crop-specific analysis of value-chains and determine market efficiencies in different root crops-growing parts of the country; • Develop systems of generating and communicating market information to different actors in the value chains of root crops; • Analyze the performance of agricultural support services (credit institutions, seed production systems, etc.,) affecting uptake and utilization of technologies of root crops and • Undertake studies on policy options that	• Update the information on characterization and diagnosis of the farming systems involving root crops and document the socio-economic and cultural values and constraints ; • Undertake studies on the rate of adoption and impacts of improved technologies of root crops; • Conduct crop-specific analysis of value-chains and determine market efficiencies in different root crops-growing parts of the country; • Develop systems of generating and communicating market information to different actors in the value chains of root crops; • Analyze the performance of agricultural support services (credit institutions, seed production systems, etc.,) affecting uptake and utilization of technologies of root crops and • Undertake studies on policy options that can positively influence root crops production and marketing.	• Update the information on characterization and diagnosis of the farming systems involving root crops and document the socio-economic and cultural values and constraints; • Undertake studies on the rate of adoption and impacts of improved technologies of root crops; • Conduct crop-specific analysis of value-chains and determine market efficiencies in different root crops-growing parts of the country; • Develop systems of generating and communicating market information to different actors in the value chains of root crops; • Analyze the performance of agricultural support services (credit institutions, seed

	can positively influence root crops production and marketing.		production systems, etc.,) affecting uptake and utilization of technologies of root crops and • Undertake studies on policy options that can positively influence root crops production and marketing.
5.2.8 Agricultural extension and gender			
Inadequate systems of: technology demonstration and popularization, and forward and backward flow of information and feedback; and limited gender mainstreaming	• Conduct participatory demonstration and popularization of available technologies and gathering feedbacks from stakeholders at different levels and agro-ecologies; • Create awareness and identify technology-cum-information dissemination and popularization methods enhancing production and consumption of root crops; • Establish a network of platforms serving various interests of stakeholders in major root crops- growing areas of the country and • Mainstream gender in the processes of development and adoption of technologies; and production, marketing and utilization of root crops.	• Conduct participatory demonstration and popularization of available technologies and gathering feedbacks from stakeholders at different levels and agro-ecologies; • Strengthen awareness creation and technology-cum-information dissemination and popularization methods enhancing production and consumption of root crops; • Strengthen the network of platforms serving various interests of stakeholders in major root crops- growing areas of the country and • Strengthening mainstreaming gender in the processes of development and adoption of technologies; and production, marketing and utilization of root crops.	• Conduct participatory demonstration and popularization of available technologies and gathering feedbacks from stakeholders at different levels and agro-ecologies; • Strengthen awareness creation and technology-cum-information dissemination and popularization methods enhancing production and consumption of root crops; • Strengthen the network of platforms serving various interests of stakeholders in major root crops- growing areas of the country and • Strengthening mainstreaming gender in the processes of development and adoption of technologies; and production, marketing and utilization of root crops.
5.2.9 Agricultural mechanization			
Lack of technologies for pre- and post-harvest operations; limited supply of prototypes; inadequate information on efficiencies of machineries at	• Inventorize and test available pre and post-harvest tools and machineries for root crops (row planters, harvesters, choppers, millers, slicers, etc.); • Adopt and adapt agricultural	• Refine available pre and post-harvest tools and machineries for root crops (row planters, harvesters, choppers, millers, slicers, etc.); • Adopt and adapt agricultural mechanization technologies appropriate for small-scale	• Develop new pre and post-harvest tools and machineries for root crops (row planters, harvesters, choppers, millers, slicers, etc.); • Adopt and adapt agricultural

hand; and lack of participatory.	mechanization technologies appropriate for small-scale farmers growing root crops.	farmers growing root crops.	mechanization technologies appropriate for small-scale farmers growing root crops.
5.2.10 Food science, postharvest management and value addition			
Lack of recommendations/ information on: storage methods; nutritional quality and anti-nutritional contents; food fortification and value addition.	• Determine the nutritional and anti-nutritional contents (starch, protein, vitamins, minerals, HCN, magnesium oxalate, etc.) of the existing varieties and elite materials of root crops; • Assess the causes and determine extent of postharvest losses of root crops across different production areas and market outlets; and develop post-harvest management technologies (harvesting, storage, handling, packaging, processing, preservation methods, etc.) and • Establish methods of developing consumer-driven and value-added alternative products of root crops including methods of food fortification.	• Strengthen determination of the nutritional and anti-nutritional contents (starch, protein, vitamins, minerals, HCN, magnesium oxalate, etc.) of root crops; • Fine-tune the results and information on the causes and determine extent of postharvest losses of root crops across different production areas and market outlets; and develop post-harvest management technologies (harvesting, storage, handling, packaging, processing, preservation methods, etc.) and • Establish methods of developing consumer-driven and value-added alternative products of root crops including methods of food fortification.	• Strengthen determination of the nutritional and anti-nutritional contents (starch, protein, vitamins, minerals, HCN, magnesium oxalate, etc.) of root crops; • Fine tune the results and information on the causes and determine extent of postharvest losses of root crops across different production areas and market outlets; and develop post-harvest management technologies (harvesting, storage, handling, packaging, processing, preservation methods, etc.) and • Establish methods of developing consumer-driven and value-added alternative products of root crops including methods of food fortification.
5.2.11 Capacity building			
Inadequate resources • Physical • Human • Finance	• Upgrade the existing, establish new, and research facilities (mini-biotech laboratories, cold rooms, stores, green houses, offices, land and irrigation for seed production, etc.); • Provide sufficient field vehicles and farm implements at coordinating and selected implementing centers; • Strengthen the number of research and technical staff through recruitment	• Upgrade the existing, establish new, and research facilities (mini-biotech laboratories, cold rooms, stores, green houses, offices, land and irrigation for seed production, etc.); • Provide sufficient field vehicles and farm implements for implementing centers; • Strengthen the number of research and technical staff through recruitment; • Improve technical cunning of the research staff through short- and long-term trainings tailored	• Upgrade the existing, establish new, and research facilities (mini-biotech laboratories, cold rooms, stores, green houses, offices, land and irrigation for seed production, etc.); • Provide sufficient field vehicles and farm implements for implementing centers; • Strengthen the number of research and technical staff

	• Improve technical cunning of the research staff through short- and long-term trainings tailored to upgrade research skills and qualifications • Provide incentives to retain staff and • Allocate sufficient budget for research and capacity building and improve efficiency of utilization.	to upgrade research skills and qualifications; • Provide incentives to retain staff and • Allocate sufficient budget for research and capacity building and improve efficiency of utilization.	through recruitment; • Improve technical cunning of the research staff through short- and long-term trainings tailored to upgrade research skills and qualifications; • Provide incentives to retain staff and • Allocate sufficient budget for research and capacity building and improve efficiency of utilization.
5.2.12 crosscutting themes			
Gender	• Organize gender disaggregated data for technology dissemination, adoption and impact of technologies; and in the course of technology demonstration, popularization, and training ensure that all female-headed households and at least 30% of beneficiaries to be women from male-headed households.		
Climate change	• Develop research programs that would adequately address the challenge to increase resilience of vulnerable communities.		
Knowledge management	• Consider modern facilities of ICT instrument in knowledge and information transfer and sharing processes.		

The Next Steps

Following the approval of the strategy document by the top management of EIAR, it is essential to prepare the implementation plan, without which this strategy is not going to reach fruition. The implementation plan document will be developed using a common Guideline adopted by the EIAR Planning, Monitoring and Evaluation Directorate to provide guidance to research teams develop implementation plans. The implementation plan will thus come out as Volume II of the research strategy, which will serve as the blueprint to guide the National Root Crops Research for the next fifteen years (2016-2030). The major contents of the implementation plan will revolve, among others, around the following topics:

- Develop implementation plan;
- Develop monitoring and evaluation plan;
- Develop impact assessment plan and
- Develop reassessment plan for the strategy .

Sub-Tropical Fruits Research Strategy

[123]

Introduction

The fruit crops citrus, avocado, mango, grapes and guava constitute EIAR's Sub-tropical Fruit Crops Research Program for which Ethiopia is endowed with agro-ecologies favorable to grow them. Nowadays fruits are becoming important crops as the number of small-holder fruit producers has been increasing at an average rate of 12% per year over the last half a decade or so and currently ca. 3.6 million households are producing fruits on average plot sizes of 120m^2. Annually about 43,500 ha of land is devoted to fruit production and a total of about 261,000 metric tons is produced from which less than 2% is exported. The sub-tropical fruits avocado, mango and citrus together contribute for more than 80% of the land and 95% of the produce. Nevertheless, the size of land and volume of production logged under sub-tropical fruits clearly represent only a diminutive proportion of the potential that the country could reap from this important sub-sector as a consequence of multiples of interactive factors hindering its expansion.

In pursuit to reverse the dire situation of the horticulture sub-sector in general and that of the fruits in particular, the Government of Ethiopia has taken a number of measures that would embolden the industry. Fundamental among these bold measures is the establishment of the Ethiopian Horticulture Development Agency. The government has also introduced attractive packages of incentives for both local and foreign investors engaged in horticultural ventures. These include such privileges as: provision of loans up to 70 percent of the investment capital; duty-free import of farm implements and equipment; and a five-year tax holiday to export-oriented growers. The government has also set a target of increasing production of fruits and vegetables from 1.28 million tons to 5.91 million tons by doubling the average productivity from 84 to 165 quintals per hectare and expanding land from 152.6 to 236 thousand hectares during the Second Growth and Transformation Plan (GTP II) period.

In order to achieve this ambitious plan, it is critical that two conditions must be fulfilled instantaneously. First, beside increasing production by the smallholders sector, large- and medium- size orchards producing sub-tropical fruits have to increase substantially. Second both sectors need to be assisted by the research system to get access to improved technologies, agricultural innovation, information and knowledge so that they would be able to produce high- quality and volume of products that are competent in both domestic as well as export markets. For the research system to attune itself with such a vital role of developing the sub-tropical fruits sub-sector, EIAR has decided to develop this long-term research strategy traversing fifteen years.

The strategy is organized in six major chapters whereby this background section together with descriptions of the rationale, vision, mission, goal and objectives constitute the introductory chapter 1. Chapter 2 provides an overview of the importance of sub-tropical fruit

crops in the Ethiopian agriculture; and food and nutrition security. Chapter 3 briefly discusses the situation analysis undertaken by assessing the internal environment as well as the external one involving all the key stakeholders to capture their reflections, concerns and desires. In chapter 4 are presented the critical issues that have been sifted out from the situation analysis and articulated as key challenges facing the sub-tropical fruit crops research program. Chapter 5 discusses the actual strategic interventions to be pursued under the various thematic areas of the research to tackle the critical issues identified. Chapter 6 provides key elements of follow up documents that need to be worked out in the next steps as they are prerequisites for effective implementation of the strategy.

Rationale

Currently, the sub-tropical fruits industry is not contributing to its level best albeit the potential it can have to: ensure food and nutrition security for millions of small-scale farming households; strengthen the opportunity for job creation and income generation; foster expansion of agro-industries, agri-business and import substitution; diversify the base for foreign earnings; and stabilize the macro-economy in general. Cognizant of its potential, the Government of Ethiopia has put in place conducive policy and regulatory frameworks that can be instrumental to propel the progress of the sub-sector which in turn would benefit small-scale and commercial growers, agro-industries, exporters and consumers of sub-tropical fruits.

Therefore, the need for maximizing utilization of potential agro-climatic, physiographic and hydrologic conditions of the country to increase production, productivity and marketability of sub-tropical fruit crops is a matter of urgency. In the present context though not only is wide the gap between what is available at research level and how much of that is being used by the farmer; but also are little the results attained thus far by the research system in comparison with the potential that could be realized from these crops. In order to create a condition where these divergent scenarios could converge and thus the commodities' potential could best be exploited, it is absolutely necessary to develop a well-defined and an all-inclusive research strategy representing and addressing the interests of all the key stakeholders involved in the value chains of the crops. Such a strategy not only creates a stronger cohesion and partnership among stakeholders but also serves as a roadmap to: guide the research program planning and implementation in line with the objectives and targets of GTP-II and that of EIAR; track records of results and lessons; and mobilize resources from national and/or international sources. It is with this rationale that the National Sub-tropical Fruit Crops Research Program (NStFCRP) - Team has developed this Research Strategy to achieve a common vision and objectives.

The NStFCRP-Team has a strong conviction that a thriving future for the commodities can be achieved only if it involves meaningful collaborations between farmers, input suppliers, exporters, actors in agribusiness and agro-industry, traders, technicians, scientists, and

others engaged in the value chains. To this end, the research team has formulated a set of principles and values that reflect its vision, mission, goal and objectives underpinning its commitments and desires as indicated below.

Vision

The vision of the National Sub-tropical Fruits Research Program is to become a leading agricultural program providing technological innovations and knowledge that can significantly contribute to improved livelihoods.

Mission

The mission of the NStFCRP is to generate, develop, adapt and promote competitive agricultural technologies, innovations, information and knowledge for improving productivity, nutritional quality and sustainable development of agriculture, agribusiness and agro-industry, supporting attainment of self-reliance and import substitution, and broadening the opportunity to exploit the potential export markets and income generations for households and the country.

Goal

The goal of the NStFCRP is to contribute to the EIAR's role towards the achievement of the sectorial objectives of (i) ensuring food security, (ii) sustainable delivering of raw materials for agro-industries and import substitution, (iii) expanding the bases for the country to gain foreign earnings from agricultural exports, and (iv) increasing livelihood resiliency and environmental sustainability while reducing vulnerability to climate change.

Objectives

The overall objective of the NStFCRP is to increase the production, productivity and quality of sub-tropical fruits through multidisciplinary and participatory research approach leading to their increased share in the national economy and advancement by understanding and applying new approaches in the whole set of the industry. Specific objects of the program, among others, include the following:

- To collect, introduce, characterize and develop varieties adaptable to different ecological and agronomic scenarios;
- To develop, adapt and promote improved agronomic and other technological packages suitable for sub-tropical fruits;
- To develop, adapt and promote conventional as well as modern techniques and methods of efficient multiplication of planting material;

- To develop, adapt and promote integrated and sustainable pest (diseases, insects, nematodes, vertebrates and weeds) management packages and
- To develop, adapt and promote appropriate postharvest (maturity indices, harvesting, handling, storage, processing and utilization) management technologies.

Importance of Sub-tropical Fruits

Fruit crops are sources of vitamins, minerals, and dietary fiber. Furthermore, vitamin ***A*** deficiency which is a major public health problem in Ethiopia predisposing children to increased risk of morbidity, mortality and disability, could in part be overcome by consuming fruits. Because many areas in Ethiopia are bestowed with a rather more Mediterranean-type of climate, they are remarkably suitable for production of sub-tropical fruits such as citrus, avocado, mango, grapes, guava and others; which are naturalized to the Ethiopian agro-ecologies.

Cultivation of fruit crops in Ethiopia probably started in the fourth century with the introduction of raisins (dried grapes), for serving the 'sacred meal' of Holy Eucharist in the church. Citrus and mango were introduced in the late 1960s and the early 1970s. Production of the crops is concentrated mainly in East Harrerghe; East Shewa; West Shewa; Arsi; SNNPR particularly Wolaita and Sidama Zones; Diredawa; Harari; South Tigray and West Gojam regions. Avocado covers about 13,678 ha of small-scale holdings with a production of 54,882 tons. Mango covers ca. 12,694 ha of land and 109,499 tons of production. The area under citrus is estimated to be about 8.5 thousand hectares; more than 80% of which is by small-holders producing annually about 72,458.8 tons of fruits; while the remaining area is under commercial plantation with annual production estimated at 20,177 tons.

Fruit processing in Ethiopia is limited mainly to extraction of fresh juice and jams with the exception of the few agro-industries involved in wineries. Awash and Castel Wineries and few growers produce grapevines for the production of wine, fresh table and raisin grapes; *Horizon* processes orange concentrate, jams and squash, and guava nectar; Africa Juice produces blended-concentrate from mango, passion fruit and papaya. Nevertheless, a range of fruit juices are imported into the country at a cost of more than 8.5 million USD annually. Both fresh and processed fruits including the Ethiopian wine have huge potential for domestic and export markets. The major export destinations are Djibouti, Sudan and Somalia, United Arab Emirates, United Kingdom, the Netherlands, Belgium, Middle-East (Yemen, Saudi Arabia), and the Russian Federation; the contribution is very weak though. Fruits and vegetable products generate annually about 877 million Ethiopian birr.

Environmentally, fruit crops have the ability to modify the micro-climate in terms of temperature, relative humidity and wind speed among other things. On farmlands, they can also improve soil permeability, aggregate stability, water holding capacity and soil temperature regimes. Integrating fruit crops in rangelands can also increase total productivity, reduce sensitivity to short-term fluctuations of climatic conditions, spread ecological risks through species diversity and improve system sustainability. Furthermore, fruit trees can provide alternative land-use options and aid more sustainable farming systems.

Situation Analysis

Two categories of forces and factors influencing the conception, formulation, action and implementation of the strategy were analyzed as external and internal factors. The external factors (influences that are outside the research system) represent both the interests of stakeholders that the research should serve and the potential role that they can play to complement or synergize the research. Specific situations or stakeholders' interests that hold back research stride or the research falls short to positively respond to, represent the challenges (C); while those that create motivation for the research represent the opportunities (O). Therefore, the situation analysis of the external factors essentially examined Opportunities and Challenges (OC) presented from the existing Political /Policy /Legal, Economic, Educational, Socio-cultural, Technological/ Technical, and Environmental (PEST) perspectives of the factors. Almost all key stakeholders, notably the Ministries of: Agriculture and Natural Resources, Trade and Industries; exporters; private industries; farmers' unions; various relevant technical units of EIAR; the Regional Research Institutes and centers; and Higher Learning Institutions involved in Sub-tropical Fruit Crops research have taken part in the process.

Analysis of the internal situation (influences that are outside the research system) was made by scrupulously examining whether or not there exists the capacity within the research system that can readily be deployed by the team to deliver outputs or promptly respond to stakeholders' quests or challenges. While the presence of such a capacity denotes the strength (S) of the team; the capacity which is required to deliver desirable outputs but falls short to exist represents the weakness (W). Therefore, analysis of the situation of internal factors examined Strengths and Weaknesses (SW) of the research team in terms of the existing resources (human, physical and fiscal); inter- and intra- disciplinary integrations, complementarities and synergies; availability of technologies, information and knowledge; and organization of internal system, and geographic coverage of the research program.

The results from the situation analysis were finally consolidated in a form of metrix whereby prevailing strengths, weaknesses, opportunities, and challenges (SWOC) were narrated with respect to their relevance to the various thematic areas that the research team is engaged in. From the situations narrated as such then were formulated the issues that the research system needs to address in the short-,

medium-, and long- term plans. Experiences of other countries with respect to the level they have reached in research and development aspects of Sub-tropical fruit crops were also examined to set a benchmark for the strategy.

Strategic Issues and Strategic Interventions

The major strategic thematic areas identified for the Sub-tropical Fruit Crops Research Program include: (1) Genetics and breeding; (2) Crop protection; (3) Agronomy and physiology; (4) Irrigation and water management; (5) Food science, postharvest management and value addition; (6) Agricultural mechanization; (7) GIS and Agro-meteorology; (8) Technology multiplication; (9) Agricultural economics; (10) Agricultural research extension and gender; (11) Capacity building; and (12) Additional cross-cutting themes. Specific strategic issues pertaining to each thematic area are presented under Table 1.

Most of the research issues identified to be addressed by the sub-tropical fruit crops research team are multi-institutional, multi-thematic, multidisciplinary, participatory, and need to be implemented in collaboration with farmers, extensionists and a wide range of other partners to be involved in the whole spectrum of the value chains. The research themes are built on the disciplinary as well as crosscutting themes briefly discussed hereunder. The strategic interventions proposed to tackle each of the issues identified for each theme, and need to be implemented during the next fifteen years on the: short-, medium- and long- term basis, are presented in Table 1 following the narrations of the disciplinary and cross-cutting thematic areas.

Research Themes

Genetics and breeding

In the years ahead, the sub-tropical fruit crops sub-sector foresees a steady demand for varieties with higher and more stable yields and acceptable quality. To keep pace with this demand, much of the focus will be on developing new varieties that are high yielding, adapted to a variety of environments, and resilient in the face of multiple stresses such as climate change, emergence of new pests and diseases, and other biotic and a biotic factors. The strategy will generally seek to accelerate crop improvement by using both conventional and modern methods and technologies that make possible handling of large volumes of genetic material and select with greater precision. This will involve stronger integration of conventional plant breeding approaches with modern tools and methods of biotechnology.

Crop protection

To make crop production more eco-efficient is to achieve yield stability and reduce the chances of crop failure due to diseases and other

pests, whose dynamics are shifting as a result of climate change. To this end, the research will focus on both host plant resistance and biological control with greater emphasis to integrated approaches of controlling diseases, insect pests, weeds and vertebrate pests through Integrated Pest Management (IPM) systems.

Agronomy and physiology

Keeping the principle of eco-efficiency, the agronomy and crop physiology endeavor will focus towards developing improved crop and soil management practices that open the way for optimal expression of genetic potential of varieties and enhancing the physiological and agronomic efficiency of the crops.

Irrigation water and nutrient management

Development of water-efficient management practices including micro-irrigation, fertigation; irrigation scheduling, etc. constitute arears of intervention related to production of sub-tropical fruit crops as they form integral components of league of crops that are best fitting for production of high-value crops under irrigation conditions.

Food science, postharvest management and value addition

The sub-tropical fruit crops have a great deal of potential in the food industry. It is therefore, essential to work on chemical characterization and profiling of the available varietes and eventually the genepool for nutritional as well as industrial values. It is also critical to develop recommendations on post-harvest technologies that would improve shelf life of the produce. Establishing alternative ways of processing the produce in view of increasing their shelf life will also open up a new vista of value addition and product diversification and thus better market opportunities for producers and options of choices for consumers.

Agricultural mechanization

The main challenges associated with agricultural machinery and post-harvest handling is the fact that producers in Ethiopia had little opportunity to employ small-scale farm implements, water pumps for irrigation, means of transportation, and storage structures that are appropriate for sub-tropical fruits. Both pre- and post- harvest operations are done manually and losses in both quantities and qualities associated with manual practices are often appalling. It is therefore, imperative to consider this field of research in this research strategy.

GIS and agro-meteorology

In formulating strategic interventions to be harnessed for achieving the objectives stipulated from the outset, it will be given due attention to GIS and agro-meteorology for better understanding of the dimensions of local climate and farming systems (physical climate, social, economic, farming systems, etc.) for targeting and developing the right technology for the right environment.

Technology multiplication and seed research

The core of research activities envisioned by the technology multiplication and seed research component of the strategy will be to: identify key problems associated with producing sufficient quantity and quality of initial material by generating basic information that would help to develop technologies addressing the challenges; adopt advanced tools of tissue culture for developing disease-free planting material of sub-tropical fruit crops; identify and adopt good practices of technology multiplication for large-scale production of the crops; and devising an internal system whereby expeditious multiplication of high-quality planting material would be effected in order to meet ever growing demand.

Agricultural economics

Agricultural economics is among the core themes of research as it plays a vanguard role in linking the biological sphere of the research and the economic validity of the results when actually being implemented by the farmer or other targets in the recommendation domains. Furthermore, it has also a key role to play in addressing policy issues that are instrumental in developing and promoting efficient, functional and sustainable value chains of the commodities constituting the Sub-tropical Fruit Crops Research Program.

Agricultural extension and gender

The agricultural extension and gender component of the research brings in stakeholders together to formulate relevant research agenda as it does also take out promising research results to the demonstration and extension processes. Notwithstanding the role the extension component plays in addressing the social aspects of the research, it is the main channel for the two-way flow of information between the research system on one hand and the end users of the research results on the other. Therefore, addressing issues related to socio-economic and research extension in the strategy is vital to attain the successes that the research team envisages. It will also be crucial to address issues related to gender equality and inclusiveness of the research process in general through this component.

Capacity building

Two important issues were identified under this topic: (i) the need for strengthening the capacity of the research team; and (ii) the stakeholders involved in the value chains in general need to have a strong, functional, influential and sustainable forum that will shape up the future of the research, production, processing, trade, and consumption of the commodities.

Crosscutting themes

Gender: The role of women in the agricultural system is critical as women contribute 70 percent of farm labour at harvesting and in post-harvest activities. But women farmers have only limited access to resources, services, land and credit. Unequal gender relations often make women more vulnerable to the effects of poverty, land degradation, and climate change. If the gender gap were eliminated, FAO asserts that total agricultural output would increase. Cognizant of this, the strategy upholds integration of gender concerns into research objectives, technology development, extension, and evaluation frameworks.

Climate change: In Ethiopia, climate change is already having an impact on the livelihoods of different communities in different corners of the country. Therefore, the research strategy will place due considerations to availing technologies that would help actors in the value chains to respond to climate change through adaptation and/or mitigation approaches.

Knowledge management (KM): Through KM interventions aided by new information technologies, it is possible to help improve smallholders' access to resources that help them improve their farm productivity and competitive ability. KM will also help to create research products in a more collaborative manner that makes them more suitable for diverse audiences. For this purpose, the research team will make results more readily available by spearheading formations of multi-stakeholder platforms that facilitate interaction and promote learning for change, mentoring, and networking.

Strategic Interventions

Table 1.Strategic interventions planned to address critical issues facing the National Sub-tropical Fruit Crops Research Program in the short-, medium- and long- terms

Thematic areas	Strategic Interventions		
	Short term (5 years)	**Medium term (10 years)**	**Long term (15 years)**
5.2.1 Genetics and breeding			
Lack of improved scion and rootstock varieties; narrow local genetic base; little/no use of biotechnological tools for variety development and maintenance; and lack of germplasm maintenance system	• Broaden the genetic bases of avocado and mango through collection and characterization of local clones; and those of citrus and grapevine through introduction of germplasm from external sources; • Introduce and adapt new scion varieties of grapevine and citrus with high yield, quality and stress- resistance/tolerance and suitable for fresh market and processing; and register those introduced heretofore; • Introduce and adapt rootstock varieties resistant/tolerant to biotic and abiotic stresses (soil-born diseases and others), with genetic capacity to impinge dwarfing and acquiescence to high-density planting systems; and register those introduced heretofore and • Maintain and conserve improved varieties and elite lines on selected research fields	• Introduce and adapt new scion varieties of grapevine and citrus with high yield, quality and stress resistance/tolerance and suitable for fresh market and processing; • Introduce and adapt new rootstock varieties resistant/tolerant to biotic and abiotic stresses (soil-born diseases and others), with genetic capacity to impinge dwarfing and acquiescence to high-density planting systems; • Undertake pedigree selections of desirable genotypes from pertinent crosses of elite clones; • Carryout mutation breeding on citrus and grapevine for improving quality traits; • Carryout genomic selection and molecular characterization of local avocado and mango germplasms and • Maintain and conserve improved varieties and elite lines on selected research fields.	• Introduce and adapt new scion varieties with high yield, quality and stress resistance/tolerance that are suitable for fresh market and processing; • Develop improved avocado and mango varieties with high- yield, quality and biotic and abiotic resistances/tolerances from clones characterized and selected using biotech tools (molecular characterization, and genomic and marker-assisted selection techniques); • Carryout extensive planned hybridizations among and between local and introduced clones to expedite introgression of desirable traits onto established cultivars and/or to develop new varieties and • Develop and employ in-vitro conservation techniques and conserve germplasms on selected research fields.
5.2.2 Crop protection			
Lack of information on biology and ecology of major pests; and inadequate IPM methods against major	• Survey and identify pests of major sub-tropical fruits in different agro-ecologies; • Study the biology and ecology of pests identified to be economically important; • Test and register introduced pesticides and bio-control methods targeted against major	• Optimize and employ molecular (PCR, RT-PCR, etc.) and serological (ELISA) techniques for diagnosis and studying the biology of disease- and insect pests; • Introduce and adapt IPM packages, IPM-compatible agrochemicals, and biological control	• Generate information on biology and physiology of pests on major fruit crops using molecular (PCR, RT-PCR, etc.) and serological (ELISA) diagnostic techniques; • Develop technologies/techniques and methods of risk assessment and prediction

diseases and insect pests	pests of sub-tropical fruits and • Introduce, adapt and develop options of IPM packages against major pre- and post- harvest pests of sub-tropical fruits.	options against major and emerging pests of sub-tropical fruits and • Develop novel botanicals and bio-control options for major pests of sub-tropical fruits.	of pest occurrences; • Develop and introduce new IPM packages for controlling newly-emerging pests and • Develop and enhance the use of biological pesticides, novel microbial products and botanicals against major pests of sub-tropical fruits.
5.2.3 Agronomy and physiology			
Limited information on: nutrient requirements for conventional and organic fruit production, cropping systems, phenology, canopy and fruit regulation practices; and cropping systems fostering nutrient recycling and environmental sustainability	• Develop INM (integrated nutrient management) packages for systems of conventional cultivation of major sub-tropical fruits; • Introduce, adapt and standardize training, pruning and flower management practices for sub-tropical fruit crops; • Study, evaluate and determine the phenology of sub-tropical fruits under different agro-ecologies and • Develop cropping systems, incorporating sub-tropical fruit crops, enhancing efficient utilization and management of natural resources under different agro-ecologies.	• Optimize INM packages for intensive cultivation of sub-tropical fruits in different agro-ecologies and growing scenarios (irrigated vs rainfed; cropping systems,.); • Introduce, adapt and standardize organic (bio- and organic- fertilizers, cultivation system, etc.) nutrient management technologies; • Introduce and standardize improved planting systems, and canopy and flower/fruit regulation practices; • Study, evaluate and determine the phenology of sub-tropical fruits under different agro-ecologies and • Fine tune recommendations on cropping systems intended for efficient utilization and management of natural resources under different agro-ecologies.	• Develop new INM technologies for intensive cultivation of sub-tropical fruits in different agro-ecologies and growing scenarios (irrigated vs rainfed; cropping systems,.); • Adapt nutrient diagnostic tools for efficient nutrient management; • Refine and strengthen recommendations on organic (bio- and organic- fertilizers, cultivation system, etc.) nutrient management technologies; • Introduce and develop standardized high-density planting systems, and canopy and flower/fruit regulation practices; • Introduce and develop technologies for manipulating/regulating plant phenology under different growing agro-ecologies and • Establish standardized cropping systems entailing efficient utilization and management of natural resources under different agro-ecologies.
5.2.4 Irrigation water and nutrient management			
Lack of crop-specific water requirements; irrigation scheduling; and water-efficient of irrigation systems appropriate for different	• Determine specific water requirements and irrigation scheduling for citrus, mango, grape and avocado across different agro-ecologies; • Introduce and adapt water-efficient irrigation systems/ technologies (drip irrigation) and	• Develop specific water requirements and irrigation scheduling for citrus, mango, grape and avocado across different agro-ecologies; • Strengthen developing water-efficient irrigation systems/ technologies (drip irrigation) and	• Refine and strengthen development of specific water requirements and irrigation scheduling for citrus, mango, grape and avocado across different agro-ecologies; • Refine and strengthen development of

AEZs	fertigation scheduling appropriate for cultivation of selected sub-tropical fruits in different agro-ecologies.	fertigation scheduling appropriate for cultivation of sub-tropical fruits in different agro-ecologies.	water-efficient irrigation systems/ technologies and fertigation scheduling appropriate for cultivation of sub-tropical fruits in different agro-ecologies.
5.2.5 Food science, postharvest management and value addition			
Heavy post-harvest losses and lack of management technologies; low quality and limited value added products; and lack of waste management practices and technologies	• Assess the causes and determine extent of postharvest losses of sub-tropical fruit crops across different production areas and market outlets; • Introduce and adapt post-harvest management technologies (harvesting, storage, handling, packaging, processing, etc.) for fresh market and processed fruit products; • Develop methods and techniques of producing semi-processed products of sub-tropical fruit crops for value addition; • Determine nutritional composition and quality of fresh and processed fruit products of sub-tropical fruits and • Identify causes and quantify magnitude of fruit wastage along the value chains of sub-tropical fruits and establish management practices and technologies that minimize wastage and open new ways of using the refuse for agricultural inputs.	• Develop affordable post-harvest management technologies of fruits for fresh market and processing; • Refine methods and techniques of producing semi-processed products of sub-tropical fruit crops for value addition; • Refine and compile nutritional composition and quality profiles of fresh and processed fruit products of sub-tropical fruits and • Refine waste minimization, management and utilization techniques/technologies and methods for agricultural use.	• Develop affordable post-harvest management technologies of fruits for fresh market and processing; • Develop methods and techniques of producing fully-processed sub-tropical fruit products for value addition; • Refine and compile nutritional composition and quality profiles of fresh and processed fruit products of sub-tropical fruits and • Develop waste management and utilization techniques/technologies and methods for different agricultural and industrial products.
5.2.6 Agricultural mechanization			
Limited use of small-scale harvesting, handling, packing and processing technologies	• Inventorize research-developed and locally available small-scale technologies, evaluate and promote those appropriate for pre and post-harvest management of sub-tropical fruits; • Adopt and adapt agricultural mechanization technologies appropriate for small-scale farmers growing sub-tropical fruits;	• Avail pre- and post-harvest mechanization technologies through adaptation to suit existing situations;	• Avail more advanced and appropriate pre- and post-harvest implements through adaptation to suit existing situations; • Adapt state-of-the-art technologies of pre- and post-harvest management and avail those which can make the country competent in the world market;

5.2.7 GIS and Agro-meteorology			
Lack of information on spatial suitability, climate characterization and modeling and adaptation responses	• Conduct spatial suitability analyses and develop suitability map of tropical fruit crops as distributed across the various AEZs and • Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall in meeting crop water requirements under rain-fed system across AEZs.	• Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall and irrigation water requirements under irrigated conditions and • Develop integrated management practices fostering crop adaptation to increased heat load in sub-tropical fruit plantations.	• Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall and irrigation water requirements under irrigated conditions and • Develop integrated management practices fostering crop adaptation to increased heat load in sub-tropical fruit plantations.
5.2.8 Technology multiplication and seed research			
Lack of standardized techniques and protocols for disease cleaning and mass propagation; and insufficient planting material of early generation clones	• Develop shoot tip and in-vitro mass propagation and disease-cleaning protocols for citrus; • Develop clonal rootstock multiplication and conventional mass propagation protocols for avocado and guava, respectively • Multiply good-quality initial planting materials through micro-propagation and conventional techniques and promote their distribution and • Establish scion banks of pedigree planting materials of improved varieties.	• Strengthen the development of shoot tip and in-vitro mass propagation and disease-cleaning protocols; • Develop standard clonal propagation techniques and protocols for rootstock multiplication; • Initiate mass multiplication of clonal rootstocks resistant to disease and abiotic stresses; • Establish protected blocks for maintaining mother stocks of scion and rootstock collections and • Undertake mass multiplication of good-quality planting materials through conventional and micro-propagation techniques and promote their distribution Undertake mass multiplication of good-quality planting materials through conventional and micro-propagation techniques and promote their distribution.	• Optimize in-vitro mass propagation and disease-cleaning protocols for the other sub-tropical fruits; • Strengthen mass multiplication of good-quality planting materials through conventional and micro-propagation techniques and promote their wide-scale distribution; • Strengthen mass multiplication of clonal rootstocks resistant to disease and abiotic stresses and • Strengthen maintenance of mother stocks of scion and rootstock collections in protected blocks.
5.2.9 Agricultural economics			
Limited information on value chains; marketing and issues of technology adoption and impacts	• Conduct crop-specific analysis of value-chains and determine market efficiencies in different sub-tropical fruit-growing parts of the country; • Develop systems of generating and communicating market information to different actors in the value chains of Sub-tropical fruits and	• Strengthen the study on the dynamics of value chains of selected Sub-tropical fruits; • Strengthen the systems developed to generate and communicate market information to different actors in the value chains of Sub-tropical fruits and • Strengthen studies on the rate of adoption and	• Strengthen the study on the dynamics of value chains of selected Sub-tropical fruits; • Strengthen the systems developed to generate and communicate market information to different actors in the value chains of Sub-tropical fruitsand • Strengthen studies on the rate of adoption

	• Undertake studies on the rate of adoption and impacts of technologies of Sub-tropical fruits (bananas, papaya and pineapple).	impacts of technologies of Sub-tropical fruits (bananas, papaya and pineapple).	and impacts of technologies of Sub-tropical fruits (bananas, papaya and pineapple).
5.2.10 Agricultural extension and gender			
Inadequate promotion and popularization of technologies; inadequate participatory technology development, evaluation, and adoption; limited gender mainstreaming in technology development and adoption, and production, marketing and utilization of sub-tropical fruits	• Create awareness and identify technology-cum-information dissemination and popularization methods enhancing production and consumption of Sub-tropical fruits in both rural and urban areas; • Establish a network of platforms serving various interests of stakeholders in major fruit growing areas of the country; • Adapt and disseminate best-bet practices on successful household-level establishment of cactus pear orchards and cactus moth and cochineal control methods in dryland areas and • Mainstream gender in the processes of development and adoption of technologies; and production, marketing and utilization of Sub-tropical fruits.	• Strengthen methods of awareness creation and technology-cum-information dissemination and popularization enhancing production and consumption of Sub-tropical fruits in both rural and urban areas; • Strengthen networks of platforms serving various interests of stakeholders in major fruit growing areas of the country; • Strengthen dissemination of best-bet practices on successful household-level establishment of cactus pear orchards and cactus moth and cochineal control methods in dryland areas and • Strengthen mainstreaming gender in the processes of development and adoption of technologies; and production, marketing and utilization of Sub-tropical fruits.	• Strengthen methods of awareness creation and technology-cum-information dissemination and popularization enhancing production and consumption of Sub-tropical fruits in both rural and urban areas; • Strengthen networks of platforms serving various interests of stakeholders in major fruit growing areas of the country; • Strengthen dissemination of best-bet practices on successful household-level establishment of cactus pear orchards and cactus moth and cochineal control methods in dry land areas and • Strengthen mainstreaming gender in the processes of development and adoption of technologies; and production, marketing and utilization of Sub-tropical fruits.
5.2.11 Capacity building			
Inadequate resources • Physical • Human • Finance	• Upgrade the existing and establish new and modern research laboratories (biotechnology, quality, soils, plant protection) and field infrastructure (irrigation, green and lath houses) at coordinating center; • Provide sufficient field vehicles and farm implements at coordinating and selected implementing centers; • Strengthen the number of research and technical staff through recruitment; • Improve technical cunning of the research staff through short- and long-term trainings tailored	• Establish new and modern research laboratories (tissue culture, quality, plant protection) and field infrastructure (irrigation and lath houses) for some implementing centers; • Equip adequately some selected centers with sufficient field vehicles and farm implements; • Improve the human resource through long-term trainings causing the research to become equipped with highly qualified multidisciplinary team of researchers; • Strengthen dexterity of researchers and technicians through short-term trainings in the	• Establishing new modern research laboratories (tissue culture, quality, plant protection) and modern infrastructure (irrigation and lath houses) for additional implementing centers; • Equip adequately some additional implementing centers with sufficient field vehicles and farm implements; • Improve the human resource through long-term trainings causing the research to become equipped with highly qualified multidisciplinary team of researchers;

	to upgrade research skills and qualifications; • Strengthen dexterity of researchers and technicians in application of specific topics like micro-grafting, postharvest, planting materials quality assurance, fertigation, knowledge management systems,; • Allocate sufficient budget for research and capacity building and improve efficiency of utilization; • Establish strong linkages between applied research and the private sector engaged in the fruits industry and • Mobilize additional project grants from resource partners and international research institutions.	application of in-vitro breeding techniques, post-harvest, planting materials quality, fertigation; • Create linkages with regional and international research, learning and development institutions; • Improve allocation and efficiency of utilization of budget for research and capacity building and; • Strengthen public-private partnership in applied research and • Mobilize additional project grants from resource partners and international research institutions.	• Strengthen skills of researchers and technicians through short-term trainings in the application of in-vitro conservation techniques and postharvest; • Strengthen linkages with regional and international research, learning and development institutions; • Improve the financial viability of the public research system; • Strengthen public-private partnership in applied research and • Mobilize additional project grants from resource partners and international research institutions.
5.2.12 crosscutting themes			
Gender	Organize gender disaggregated data for technology dissemination, adoption and impact of technologies; and in the course of technology demonstration, popularization, and training ensure that all female-headed households and at least 30% of beneficiaries to be women from male-headed households		
Climate change	Develop research programs that would adequately address the challenge to increase resilience of vulnerable communities		
Knowledge management	Consider modern facilities of ICT instrument in knowledge and information transfer and sharing processes		

The Next Steps

Following the approval of the strategy document by the top management of EIAR, it is essential to prepare the implementation plan, without which this strategy is not going to reach fruition. The implementation plan document will be developed using a common Guideline adopted by the EIAR Planning, Monitoring and Evaluation Directorate to provide guidance to research teams develop implementation plans. The implementation plan will thus come out as Volume II of the research strategy, which will serve as the blueprint to guide the National Sub-tropical Fruit Crops Research for the next fifteen years (2016-2030). The major contents of the implementation plan will revolve, among others, around the following topics:

- Develop implementation plan;
- Develop monitoring and evaluation plan;
- Develop impact assessment plan and
- Develop reassessment plan for the strategy.

Temperate Fruits Research Strategy

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Introduction

Ethiopia is endowed with favorable agro-ecologies to grow a variety of temperate fruit crops, which are grouped into two as; Pome-fruits constituting Apple - Malus communis;Pear - Pyrus communis, and (Quince - Cydonia oblonga; and Stone-fruits Peach - Persica; Plum - Prunus domestica, (vi) Almond- Prunus communis,; Apricot - Prunus armeniaca,;Olive - Olea europaea; Strawberry - Fragaria vesca; Cherries - Prunus spp., and Nut-fruits (walnut and chestnuts). Nowadays, fruits are becoming important crops in Ethiopia as the number of small-holder fruit producers is increasing at 12% per year and ca. 3.6 million households are producing fruits on average plot sizes of $120m^2$. The majority of producers and production land are linked with tropical fruits grown mainly in the hotter climates of the lowlands. Annually about 43,500 ha of land is devoted for production of fruits and a total of about 261,000 metric tons is produced from which less than 2% is exported. The size of land and volume of production logged under fruits clearly represent only a dismal proportion of the potential that the country could reap from this important sub-sector as a consequence of multiples of interactive factors hindering its expansion.

In pursuit of reversing the situation, Ethiopian government has taken a number of measures that would embolden the horticulture industry in general. Fundamental among these bold measures is the establishment of the Ethiopian Horticulture Development Agency. The government has also introduced attractive packages of incentives for both local and foreign investors engaged in the horticulture sector. These include such privileges as: provision of loans up to 70 percent of the investment capital; duty-free import of farm implements and equipment; and a five-year tax holiday to export-oriented growers. The government has also set a target to increase the production of fruits and vegetables from 1.28 million tons to 5.91 million tons by doubling the average productivity from 84 q to 165 q per ha and expanding land from 152.6 thousand ha to 236 thousand ha during the second growth and transformation plan (GTP II) period.

In order to achieve this ambitious plan, it is critical that two conditions must be fulfilled instantaneously. First, beside increasing the smallholders sector, the number of large- and medium- size orchards producing temperate fruits has to increase substantially; and second both sectors need to be assisted by the research system to get access to improved technologies, agricultural innovation, information and knowledge so that they would be able to produce high- quality and volume of products that are competent in both domestic as well as export markets. For the research system to attune itself with such a vital role of developing the temperate fruits sub-sector, EIAR has decided to develop this long-term research strategy traversing fifteen years.

The strategy is organized in six major chapters whereby this background section together with descriptions of the rationale, vision, mission, goal and objectives constitute the introductory chapter 1. Chapter 2 provides an overview of the importance of temperate fruit crops in the Ethiopian agriculture; and food and nutrition security. Chapter 3 briefly discusses the process of situation analysis undertaken by assessing the internal environment as well as the external one involving all the key stakeholders to capture their reflections, concerns and desires. In chapter 4 are presented the critical issues that have been sifted out from the situation analysis and articulated as key challenges facing the temperate fruit crops research program. Chapter 5 discusses the actual strategic interventions to be pursued under the various thematic areas of the research to tackle the critical issues identified. Chapter 6 provides key elements of follow up documents that need to be worked out in the next steps as they are prerequisites for effective implementation of the strategy.

Rationale

Currently, the temperate fruits industry is not contributing to its level best albeit the potential it can have to: ensure food and nutrition security for millions of small-scale farming households; strengthen the opportunity for job creation and income generation; foster expansion of agro-industries, agri-business and import substitution; diversify the base for foreign earnings; and stabilize the macro-economy in general. Cognizant of its potential, the Government of Ethiopia has put in place conducive policy and regulatory frameworks that can be instrumental to propel the progress of the sub-sector which in turn would benefit small-scale and commercial growers, agro-industries and consumers alike of temperate fruits.

Therefore, the need for maximizing utilization of potential agro-climatic, physiographic and hydrologic conditions of the country to increase production, productivity and marketability of temperate fruit crops is a matter of urgency. In the present context though not only is wide the gap between what is available at research level and how much of that is being used by the farmer; but also are little the results attained thus far by the research system in comparison with the potential that these crops can provide. In order to create a condition where these divergent scenarios could converge and thus the commodities' potential could be exploited the best level possible, it is absolutely necessary to develop a well-defined and an all-inclusive research strategy representing and addressing the interests of all the key stakeholders involved in the value chains of the crops. Such a strategy not only creates a stronger cohesion and partnership among stakeholders but also serves as a roadmap to: guide the research program planning and implementation in line with the objectives and targets of GTP-II and that of EIAR; track records of results and lessons; and mobilize resources from national and/or international sources. It is with this rationale that the National Temperate Fruit Crops Research Program (NTFRP) - Team has developed this Research Strategy to achieve a common vision and objectives.

The NTFRP-Team has a strong conviction that a thriving future for the commodities can be achieved only if it involves meaningful collaborations between farmers, input suppliers, exporters, actors in agribusiness and agro-industry, traders, technicians, scientists, and others engaged in the value chains. To this end, the research team has formulated a set of principles and values that reflect its vision, mission, goal and objectives underpinning its commitments and desires as indicated below.

Vision

The vision of the National Temperate Fruits Research Program is to see the research system became center of excellence in temperate fruits research, technology, information and knowledge; and the country's temperate fruit sub-sector to be sustainably transformed into a vibrant and productive economic sector through increased productivity and improved quality

Mission

The mission of the NTFRP is to generate, develop, adapt and promote competitive agricultural technologies, innovations, information and knowledge for improving productivity, nutritional quality and sustainable development of agriculture, agribusiness and agro-industry, supporting attainment of self-reliance and import substitution, and broadening the opportunity to exploit the potential export markets and income generations for households and the country

Goal

The goal of the NTFRP is contribute to the EIAR's role towards the achievement of the sectorial objectives of (i) ensuring food security, (ii) sustainable delivering of raw materials for agro-industries and import substitution, (iii) expanding the bases for the country to gain foreign earnings from agricultural exports, and (iv) increasing livelihood resiliency and environmental sustainability while reducing vulnerability to climate change

Objectives

The overall objective of the NTFRP is to increase the production, productivity and quality of temperate fruits through multidisciplinary and participatory research approach that ultimately will lead to increased share of temperate fruits in the national economy and

advancement in understanding and applying new approaches in the whole set of the industry. Specific objects of the program, among others, are:

- To develop technologies, empower smallholder growers and address major temperate fruits-related production, productivity and quality problems;
- To collect, characterize and conserve germplasm resources for research use through the participation of interdisciplinary teams;
- To forge collaborations and coordination of research projects and other related activities on temperate fruits being undertaken by research centers and higher learning institutions;
- To generate and popularize improved technologies addressing economic, market and nutritional needs;
- To ensure sustainable food and nutrition security, enhance import substitution, provide raw materials for agro-industries relying on temperate fruits, and broaden the base for the country to gain foreign earnings and
- To improve the livelihoods of producers as well as other actors involved in the value chains of temperate fruits.

Importance of Temperate Fruits

Temperate fruits especially apple was introduced into the tropical mountains of southwestern Ethiopia in the 1970's by missionaries; and essentially they are all introductions. Some productive low-chill apple trees have been restricted mainly to areas with a humid tropical mountain climate in the southern Ethiopia. The culture of temperate fruits is new to Ethiopia and the research hitherto was very much limited to identifying varieties adaptable to some target areas with a set of specific climatic factors. Properly designed and implemented fruit production schemes can help to: alleviate poverty; ensure food and nutrition security; improve livelihoods and employment; maintain ecosystems and good health; conserve biodiversity; and mitigate greenhouse effects by carbon sequestration. Temperate fruits can contribute to the horticulture industry by providing a wider option of choice and access in the face of ever increasing domestic demand for fruits. Temperate fruits that can suitably grow in Ethiopia are grouped under two categories depending on their requirements for low temperatures, low- and medium- chill. Over the past years, temperate fruits have emerged as one of the potential horticultural crops in accelerating economic growth. The SNNP, Oromia, Amhara, and Tigray Regions are the major producers of temperate fruits, particularly of apple, peach, plum, pear and strawberry. Propagation of planting material has become an important business in Chencha (SNNPR), Degem (Oromia), Agena (Tigray) and Kosober (Amhara) areas whilst the area under apple production is expanding at a faster rate and produces are often destined to Addis Ababa or larger cities in their environs. Owing to the combined effects of successful apple

seedling business, increased demand for apples in local and national markets and the collective efforts of various stakeholders, investment in apple production has become an attractive venture in the highlands of Ethiopia.

Nutritionally temperate fruits are: very nourishing, aromatic and delicious and thus are considered healthy as they are rich in vitamins, calcium, phosphorus, potassium and organic acids; not to mention their veritable potency in preventing a host of pathological ailments and disorders. Therefore, like most edible horticultural crops, today temperate fruits constitute part of the rapidly growing league of new food stuffs relished by ordinary households in Ethiopia. Although their present state of processing is yet rudimentary, they can potentially be processed into versatile products such as concentrated fruit juice; sauce; slices; chips; vinegar; 'pop wine'; cider; various canned and dried fruit products; and ingredients of cakes, pies and pastries.

Fruit trees can also play a significant role in conserving natural ecosystems through: reducing soil erosion and nutrient leaching; bring nutrients up from deeper soil layers to the upper and thus increase their redistribution in the root zone; serve as a possible conduit for groundwater cleanup and recharge; and carbon sequestration for mitigation of greenhouse effects. Fruit trees can also serve as contour hedge rows in areas of high slope to encumber forces eroding soil. Integrating fruit crops in farm and rangelands can increase total productivity, reduce sensitivity to short-term fluctuations by spreading risk through species diversity and increase overall system sustainability.

Situation Analysis

Two categories of forces and factors influencing the conception, formulation, action and implementation of the strategy were analyzed as external and internal factors. The external factors (influences that are outside the research system) represent both the interests of stakeholders that the research should serve and the potential role that they can play to complement or synergize the research. Specific situations or stakeholders' interests that hold back research stride or the research falls short to positively respond to, represent the challenges (C); while those that create motivation for the research represent the opportunities (O). Therefore, the situation analysis of the external factors essentially examined Opportunities and Challenges (OC) presented from the existing Political /Policy /Legal, Economic, Educational, Socio-cultural, Technological/ Technical, and Environmental (PEST) perspectives of the factors. Almost all key stakeholders, notably the Ministries of: Agriculture and Natural Resources, Trade and Industries; exporters; private industries; farmers'

unions; various relevant technical units of EIAR; the Regional Research Institutes and centers; and Higher Learning Institutions involved in Temperate Fruit Crops research have taken part in the process.

Analysis of the internal situation (influences that are outside the research system) was made by scrupulously examining whether or not there exists the capacity within the research system that can readily be deployed by the team to deliver outputs or promptly respond to stakeholders' quests or challenges. While the presence of such a capacity denotes the strength (S) of the team; the capacity which is required to deliver desirable outputs but falls short to exist represents the weakness (W). Therefore, analysis of the situation of internal factors examined Strengths and Weaknesses (SW) of the research team in terms of the existing resources (human, physical and fiscal); inter- and intra- disciplinary integrations, complementarities and synergies; availability of technologies, information and knowledge; and organization of internal system, and geographic coverage of the research program.

The results from the situation analysis were finally consolidated in a form of metrix whereby prevailing strengths, weaknesses, opportunities, and challenges (SWOC) were narrated with respect to their relevance to the various thematic areas that the research team is engaged in. From the situations narrated as such then were formulated the issues that the research system needs to address in the short-, medium-, and long- term plans. Experiences of other countries with respect to the level they have reached in research and development aspects of temperate fruit crops were also examined to set a benchmark for the strategy.

Issues, Themes and Strategic Interventions

The major strategic thematic areas identified for the Temperate Fruit Crops Research Program include: Genetics and breeding; Crop protection; Agronomy and physiology; Irrigation water and nutrient management; Food science, postharvest management and value addition; Agricultural mechanization; GIS and agro-meteorology; Technology multiplication and seed research; Agricultural economics; Agricultural research extension and gender; Capacity building; and Additional cross-cutting themes.

Most of the research issues identified to be addressed by the temperate fruit crops research team are multi-institutional, multi-thematic, multidisciplinary, participatory, and need to be implemented in collaboration with farmers, extensionists and a wide range of other partners to be involved in the whole spectrum of the value chains. The research themes are built on the disciplinary as well as crosscutting

themes briefly discussed hereunder. The strategic interventions proposed to tackle each of the issues identified for each theme, and need to be implemented during the next fifteen years on the: short-, medium- and long- term basis are presented in Table1 following the narrations of the disciplinary and cross-cutting thematic areas.

Research Themes

Genetics and breeding

In the years ahead, the Temperate Fruit crops sub-sector foresees a steady demand for varieties with higher and more stable yields and acceptable quality. To keep pace with this demand, much of the focus will be on developing new varieties that are high yielding, adapted to a variety of environments, and resilient in the face of multiple stresses such as climate change, emergence of new pests and diseases, and other biotic and a biotic factors. The strategy will generally seek to accelerate crop improvement by using both conventional and modern methods and technologies that make possible handling of large volumes of genetic material and select with greater precision. This will involve stronger integration of conventional plant breeding approaches with modern tools and methods of biotechnology.

Crop protection

To make crop production more eco-efficient is to achieve yield stability and reduce the chances of crop failure due to diseases and other pests, whose dynamics are shifting as a result of climate change. To this end, the research will focus on both host plant resistance and biological control with greater emphasis to integrated approaches of controlling diseases, insect pests, weeds and vertebrate pests through Integrated Pest Management (IPM) systems.

Agronomy and physiology

Keeping the principle of eco-efficiency, the agronomy and crop physiology endeavor will focus towards developing improved crop and soil management practices that open the way for optimal expression of genetic potential of varieties and enhancing the physiological and agronomic efficiency of temperate fruit crops.

Irrigation water and nutrient management

Development of water-efficient management practices including micro-irrigation, fertigation; irrigation scheduling, etc. constitute arears of intervention related to production of temperate fruit crops as they form integral components of league of crops that are best fitting for production of high-value crops under irrigation conditions.

Food science, postharvest management and value addition

The temperate fruit crops have a great deal of potential in the food industry. It is therefore, essential to work on chemical characterization and profiling of the available varietes and eventually the genepool for nutritional as well as industrial values. It is also critical to develop recommendations on post-harvest technologies that would improve the shelf life of the crops. Establishing alternative ways of processing the produce in view of increasing their shelf life will also open up a new vista of value addition and product diversification and thus better market opportunities for producers and options of choices for consumers.

Agricultural mechanization

The main challenges associated with agricultural machinery and post-harvest handling is the fact that producers in Ethiopia had little opportunity to employ small-scale farm implements, water pumps for irrigation, means of transportation, and storage structures that are appropriate for temperate fruits. Both pre- and post- harvest operations are done manually and losses in both quantities and qualities associated with manual practices are often appalling. It is therefore, imperative to consider this field of research in this research strategy.

GIS and agro-meteorology

In formulating strategic interventions to be harnessed for achieving the objectives stipulated from the outset, it will be given due attention to GIS and agro-meteorology for better understanding of the dimensions of local climate and farming systems (physical climate, social, economic, farming systems,.) for targeting and developing the right technology for the right environment.

Technology multiplication and seed research

The core of research activities envisioned by the technology multiplication and seed research component of the strategy will be to: identify key problems associated with producing sufficient quantity and quality of initial material by generating basic information that would help to develop technologies addressing the challenges; adopt advanced tools of Tissue culture for developing disease-free

planting material of temperate fruit crops; identify and adopt good practices of technology multiplication for large-scale production of the crops; and devising an internal system whereby expeditious multiplication of high-quality planting material would be effected in order to meet ever growing demand.

Agricultural economics

Agricultural economics is among the core themes of research as it plays a vanguard role in linking the biological sphere of the research and the economic validity of the results when actually being implemented by the farmer or other targets in the recommendation domains. Furthermore, it has also a key role to play in addressing policy issues that are instrumental in developing and promoting efficient, functional and sustainable value chains of the temperate fruit crop commodities.

Agricultural extension and gender

The agricultural extension and gender component of the research brings in stakeholders together to formulate relevant research agenda as it does also take out promising research results to the demonstration and extension processes. Notwithstanding the role the extension component plays in addressing the social aspects of the research, it is the main channel for the two-way flow of information between the research system on one hand and the end users of the research results on the other. Therefore, addressing issues related to socio-economic and research extension in the strategy is vital to attain the successes that the research team envisages. It will also be crucial to address issues related to gender equality and inclusiveness of the research process in general through this component.

Capacity building

Two important issues were identified under this topic: (i) the need for strengthening the capacity of the research team; and (ii) the stakeholders involved in the temperate fruit crops value chains in general need to have a strong, functional, influential and sustainable forum that will shape up the future of the research, production, processing, trade, and consumption of the commodities.

Crosscutting themes

Gender: The role of women in the agricultural system is critical as women contribute 70 percent of farm labour at harvesting and in post-harvest activities. But women farmers have only limited access to resources, services, land and credit. Unequal gender relations often make women more vulnerable to the effects of poverty, land degradation, and climate change. If the gender gap were eliminated, FAO asserts that total agricultural output would increase. Cognizant of this, the strategy upholds integration of gender concerns into research objectives, technology development, extension, and evaluation frameworks.

Climate change: In Ethiopia, climate change is already having an impact on the livelihoods of different communities in different

corners of the country. Therefore, the research strategy will place due considerations to availing technologies that would help actors in the value chains of temperate fruit crops to respond to climate change through adaptation and/or mitigation approaches.

Knowledge management (KM): Through KM interventions aided by new information technologies, it is possible to help improve smallholders' access to resources that help them improve their farm productivity and competitive ability. KM will also help to create research products in a more collaborative manner that makes them more suitable for diverse audiences. For this purpose, the research team will make results more readily available, spearhead formations of multi-stakeholder platforms that facilitate interaction and promote learning for change, mentoring, and networking.

Strategic Interventions and Expected Outputs

Table 1 Strategic interventions planned to address critical issues facing the National Temperate Fruit Crops Research Program in the short-, medium-and long-term

Thematic areas	Strategic Interventions		
	Short term (5 years)	**Medium term (10 years)**	**Long term (15 years)**
5.2.1 Genetics and breeding			
Narrow genetic base, limited germplasm source, little/no basic genetic information for traits of interest (e.g. gene action and inheritance of traits); negligible breeding work; little/no application of modern biotech tools; and no system of germplasm maintenance	• Introduce new germplasm materials of temperate fruits with low-chill requirements and develop scion- and rootstock- varieties with desirable traits; • Establish internal quarantine system to control foreign pests; • Take inventory of materials of temperate fruits introduced, collected, screened and evaluated in the country; • Establish basic genetic information on traits of interest (e.g. gene actions and inheritance of traits) for future use in variety development; • Prepare electronic and print (in the form of a booklet) registries of adapted or elite clones of temperate fruits as part of a data base for public use; • Study the flower biology of representative stocks of temperate fruits; and establish crossing	• Introduce new germplasm materials of temperate fruits with low-chill requirements and develop scion- and rootstock- varieties with desirable traits; • Screen and evaluate new collections and introductions; • Establish basic genetic information on traits of interest (e.g. gene actions and inheritance of traits) for future use in variety development; • Use biotechnological tools for enhancement of germplasm including the use of somaclonal variation in creating genetic variability; • Update and expand the data base on the registry of adapted or elite clones in easy-to-use formats that can be widely accessed • Widen genetic variability through intentional-crossings of individuals that can ostensibly result in populations from which selection of superior types could be made; • Develop and test *in-vitro* MAS breeding for yield, desirable quality traits and stress tolerance; and test, *in-vivo,* the clones	• Press forward aggressively enhancement of germplasm using both conventional and biotechnological tools such as gene mapping and bioinformatics; • Identifying new sources of scion and rootstock varieties with desirable traits; • Establish basic genetic information on traits of interest (e.g. gene actions and inheritance of traits) for future use in variety development; • Update and expand the data base on the registry of adapted or elite clones in easy-to-use formats that can be widely accessed; • Widen genetic variability through intentional-crossings of individuals that can ostensibly result in populations from which selection of superior types could be made; • Develop and generate clones and varieties with desirable traits of yield, quality and stress; • Characterize and study genetic

	blocks with clones/varieties containing desirable traits; • Initiate capacity building on research topics of MAS, *in-vitro* breeding and maintenance techniques and tissue culture; • Maintain and conserve adapted and elite clones of temperate fruits and • Compile morphological descriptors for collected rootstock varieties.	generated in this manner to verify conformity of the methods for the traits under question; • Characterize and study genetic variations of the crops using biotechnological tools; • Optimize biotechnological protocols and procedures for hard-to-root species and • Develop *in-vitro* protocols for conservation of clones of selected fruit crops.	variations of the crops using biotechnological tools; • Optimize biotech protocols and procedures for crops not yet done; • Study the molecular bases of chilling-requirements in different apple cultivars and • Start application of *in-vitro* techniques for conserving elite varieties and clones of fruits.
5.2.2 Crop protection			
Inadequate knowledge and skill on prevalence, phenology, population dynamics and ecology of economically important pests; insufficient IPM approaches; and inadequate use of molecular diagnostic techniques and management practices against economically important pests	• Establish basic data on identification and distribution of major and potential pests (insect pests - wooly aphids, rosy leaf-curling aphid; diseases - alternaria leaf spot, apple scab, powdery mildew, and apple canker; and weeds) of temperate fruits in all production areas and potential agro-ecologies; • Study the biology, epidemiology, race/biotypes and dynamics of major diseases of temperate fruits; • Introduce and test IPM-compatible agrochemicals, biological pesticides and botanicals against major pests of fruits and • Assess and document knowledge and biological control agents of major pests (insect pests, diseases and weeds) of temperate	• Study the phenology of major pests; and biology, epidemiology, race/biotypes and dynamics of major diseases; • Develop disease indexing; • Develop and register appropriate management/control methods/measures for the major pests (insect pests, diseases and weeds) of temperate fruits; • Develop botanicals for major insects and diseases and • Identify genes for disease resistance using molecular approaches.	• Study population dynamics and ecology of major pests of temperate fruits; • Develop effective integrated disease management (IDM) methods against major diseases; • Develop new and more effective botanicals against major postharvest diseases; • Identify disease resistance genes using molecular approaches and • Study inheritance of the resistance genes and transfer them onto established varieties.

	fruits.		
5.2.3 Agronomy and physiology			
Agronomic and nutrient management practices that are specific to growing AEZs; crop load management practices; and eco-physiological and dormancy dynamic responses of temperate fruits to different AEZs	• Establish planting systems and population densities appropriate for the different temperate fruits and growing environments; • Establish nutrient requirements, soil-test-based fertilizer rates and application methods and time for temperate fruits in different AEZs; • Identify suitable seed stratification methods for peach; • Determine rootstock population density for production of good-quality seedlings of different temperate fruits and • Establish appropriate canopy management practices and standardize the flower and fruit management and • Generate preliminary information on eco-physiological relations and responses of fruit varieties with various categories of chilling requirements and ecological niches.	• Establish appropriate planting systems and population densities suitable for multiple cropping such as intercropping, strip cropping; • Establish nutrient requirements, soil-test-based fertilizer rates and application methods and time for new crops and varieties of temperate fruits and AEZs; • Develop integrated soil fertility management practices; • Establish appropriate canopy management practices and standardize the flower and fruit management for new crops and varieties of temperate fruits and AEZs and • Identify determinants of yield and impact of temperature to induce growth cessation and dormancy.	• Establish appropriate planting systems and population densities of new crops and varieties suitable for multiple cropping such as intercropping, strip cropping, • Establish nutrient requirements, soil-test-based fertilizer rates and application methods and time for new crops and varieties of temperate fruits and AEZs • Refine canopy management practices and standardize the flower and fruit management for new crops and varieties of temperate fruits and AEZs.
5.2.4 Irrigation water and nutrient management			
Crop water requirement, irrigation scheduling, efficient irrigation systems, and fertigation	• Determine crop-water requirements and irrigation scheduling (frequency, quantity, and timing of irrigation) to optimize crop growth and productivity of	• Determine crop-water requirements and irrigation scheduling (frequency, quantity, and timing of irrigation) to optimize crop growth and productivity of new crops and varieties of temperate fruits;	• Determine crop-water requirements and irrigation scheduling (frequency, quantity, and timing of irrigation) to optimize crop growth and productivity of new crops and varieties of

	temperate fruits; • Establish effective and water-efficient irrigation systems such as drip irrigation with a double purpose of watering in conjunction with application of fertilizer (fertigation).	• Identify critical growth stages to be synchronized with availability of irrigation water and • Undertake elaborated studies on fertigation.	temperate fruits; • Develop water-use models capturing variables of crop and environmental factors for optimum irrigation scheduling in orchards.
5.2.5 Food science, postharvest management and value addition			
Postharvest losses and management technologies; physicochemical quality determination; and value addition	• Determine extents of postharvest losses of major temperate fruits and develop appropriate packing material for fresh market and processing of produce; • Develop/adopt standards and fruit quality test procedures for temperate fruits and products; • Determine the physicochemical quality profiles of fresh fruit and semi-processed products of adapted temperate fruit varieties; • Identify and develop value added products (table fruits; juice; cider - *an alcoholic beverage made from the fermented juice of fruits*; piesand • Study the influences of varieties and environment on the quality of temperate fruits and processed products.	• Develop recipes for different products of the temperate fruits; • Establish appropriate mashing and fermentation conditions for temperate fruits to be used as raw material for cider and other fermented products; • Determine the physicochemical quality profiles of fresh fruit and semi-processed products of widely-grown varieties and elite materials on pipeline; • Undertake studies on the influences of genotypes and environment on the quality profile of fresh and processed products of temperate fruits and • Fine tune and promote value addition in alternative products of temperate fruits (juice; cider; pies; flour; sloes- *small, sour, blackish fruit used for flavoring;* and the likes).	• Refine and promote results and achievements from preservation and postharvest studies; • Develop modified atmospheric storage and ethylene management; • Expand determination of the physicochemical quality profiles of fresh fruit and semi-processed products of temperate fruits and • Refine and promote alternative value addition and product development in .temperate fruits
5.2.6 Agricultural mechanization			
Small scale harvesting, handling, packing and processing technologies	• Inventorize, evaluate and adopt existing and potential pre- and post-harvest mechanization	• Avail pre- and post-harvest mechanization technologies through adaptation to suit existing situations	• Adapt state of the art technologies appropriate for production and processing of temperate fruits that can

	technologies suitable for temperate fruits		leverage the country to benefit from its competitive advantage of proximity to potential export markets
5.2.7 GIS and agro-meteorology			
Lack of information on spatial suitability analyses, climate characterization and modeling, and adaptation responses to curb risks associated with climate change on temperate fruits	• Undertake spatial suitability analyses and mapping of temperate fruits under various AEZs; • Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall in meeting crop water requirements under rain-fed system across AEZs.	• Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall and water requirements under irrigated agriculture; • Develop integrated management practices fostering crop adaptation to increased heat load in temperate fruit plantations.	• Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall and water requirements under irrigated agriculture; • Develop integrated management practices fostering crop adaptation to increased heat load in temperate fruit plantations.
5.2.8 Technology multiplication and seed research			
Quality control standard and system for seedling multiplication; and poor linkage with stakeholders; and insufficient availability of improved clones or varieties	• Optimize nursery management packages for production of high-quality and quantity seedlings of temperate fruits; • Prepare seedling production manuals and guidelines for major temperate fruits; • Establish internal quality control system and standards for multiplication of good-quality seedlings of temperate fruits and • Establish application of plant tissue culture and micro-propagation techniques for mass production of good-quality planting material of temperate fruits.	• Develop, through multidisciplinary approach, improved pre- and post- nursery handling and management practices and techniques for production of good-quality rootstock and grafted-seedlings; • Strengthen internal quality control system and standards for multiplication of good-quality seedlings of temperate fruits and • Expand application of plant tissue culture and micro-propagation techniques for both mass production of good-quality planting material and maintenance of temperate fruits.	• Determine standards of both physical (length, stem diameter and vigor) and health (freedom from pests) parameters of rootstock-quality seedlings for different genotypes and environments; • Enhance participation of farmers, private sector and community organizations in production and multiplication of good-quality planting material and seedling of both rootstock and grafted-seedlings and • Expand application of plant tissue culture and micro-propagation techniques for both mass production of good-quality planting material and maintenance of temperate fruits.

5.2.9 Agricultural economics			
Limited information on value chains of temperate fruits; and Lack of studies on basic information of temperate fruits	• Map the value chain actors and stakeholders of the various temperate fruits and determine market efficiencies; • Develop viable business models for multiplication and marketing of fruit seedlings and • Determine the production economics (cost, revenue and profit analysis) and investment opportunities for production of temperate fruits.	• Update the work on mapping the value chain actors and stakeholders of the various temperate fruits and determine market efficiencies; • Generate basic information and knowledge on the status of adoption, diffusion and impact of temperate fruit technologies and • Update the production economics (cost, revenue and profit analysis) and investment opportunities for production of temperate fruits fits.	• Update the work on mapping the value chain actors and stakeholders of the various temperate fruits and determine market efficiencies; • Update the basic information and knowledge on the status of adoption, diffusion and impact of temperate fruit technologies; • Update the production economics (cost, revenue and profit analysis) and investment opportunities for production of temperate fruits fits.
5.2.10 Agricultural extension and gender			
Inadequate methods of promotion and popularization of fruit production and consumption in urban and rural areas; and limited stance of gender mainstreaming in production, marketing and utilization of fruits	• Strengthen research-extension-farmers linkages and participatory research; • Enhance community-based seedling multiplication schemes (cooperatives, fruit-grower groups); • Enhance production and distribution of good-quality seedlings of temperate fruits through increased participations of farmers and community-organizations in nursery establishment and seedling production and • Characterize and mainstream gender roles and perspectives in the value chains of temperate fruits.	• Strengthen and also develop new models of production and distribution of good-quality seedlings of temperate fruits through increased participations of farmers and community-organizations in nursery establishment and seedling production; • Strengthen the process of mainstreaming and role of gender in the value chains of temperate fruits.	• Strengthen and also develop new models of production and distribution of good-quality seedlings of temperate fruits through increased participations of farmers and community-organizations in nursery establishment and seedling production; • Strengthen the process of mainstreaming and role of gender in the value chains of temperate fruits.

5.2.11 Capacity building			
Skilled human resources in modern tools for crop improvement and quality analysis; and limited research infrastructure (lab facilities, standard store, greenhouse, nurseries); and poor linkage of research system with other stakeholders along the value chain	• Provide short-term trainings on modern tools of plant breeding and utilization of modern equipment for analysis; • Establish standard greenhouse and avail some basic biotechnological lab materials (Laminal hood, Gel electrophoresis and PCR, etc.) and equipment for quality analysis; • Capacitate selected fruit nurseries in the potential regions for multiplication of seedlings of adapted varieties and • Establish temperate fruit stakeholders' platform.	• Provide trainings raising skills or specializations of technicians or researchers in modern tools for crop improvement and quality analysis ; • Modernize the lab facilities to attain state of the art of biotechnological and quality analyses and • Strengthen the platforms established for promoting development of the temperate fruits sub-sector.	• Provide trainings raising skills or specializations of technicians or researchers in modern tools for crop improvement and quality analysis; • Modernize the lab facilities to attain state of the art of biotechnological and quality analyses; • Strengthen the platforms established for promoting development of the temperate fruits sub-sector nationally and forge international networking.
5.2.12 crosscutting themes			
Gender	Organize gender disaggregated data for technology dissemination, adoption and impact of technologies; and in the course of technology demonstration, popularization, and training ensure that all female-headed households and at least 30% of beneficiaries to be women from male-headed households		
Climate change	Develop research programs that would adequately address the challenge to increase resilience of vulnerable communities		
Knowledge management	Consider modern facilities of ICT instrument in knowledge and information transfer and sharing processes		

The Next Steps

Following the approval of the strategy document by the top management of EIAR, it is essential to prepare the implementation plan, without which this strategy is not going to reach fruition. The implementation plan document will be developed using a common Guideline adopted by the EIAR Planning, Monitoring and Evaluation Directorate to provide guidance to research teams develop implementation plans. The implementation plan will thus come out as Volume II of the research strategy, which will serve as the blueprint to guide the National Temperate Fruit Crops Research for the next fifteen years (2016-2030). The major contents of the implementation plan will revolve, among others, around the following topics:

- Develop implementation plan;
- Develop monitoring and evaluation plan;
- Develop impact assessment plan and
- Develop reassessment plan for the strategy.

Tropical Fruits Research Strategy

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Introduction

The fruit crops Banana, Papaya, Pineapple, Passion fruit, Date palm, and Cactus pear which are grown mainly in the hotter climates of the lowlands constitute EIAR's Tropical Fruit crops Research Program. Ethiopia is endowed with agro-ecologies favorable to grow these crops; and more than 38 fruit species are currently under various levels of cultivation in Ethiopia. Nowadays, fruits are becoming important crops in Ethiopia as the number of small-holder fruit producers has been increasing at an average rate of 12% per year over the last half a decade or so and currently ca. 3.6 million households are producing fruits on average plot sizes of 120m^2. The majority of producers and production land are linked with tropical fruits. Annually 43,500 ha of land is devoted to fruit production and a total of 261,000 metric tons is produced from which less than 2% is exported. The size of land and volume of production logged under fruits clearly represent only a diminutive proportion of the potential that the country could reap from this important sub-sector as a consequence of multiples of interactive factors hindering its expansion.

In pursuit to reverse the dire situation of the horticulture sub-sector in general and that of the fruits in particular, the Government of Ethiopia has taken a number of measures that would embolden the industry. Fundamental among these bold measures is the establishment of the Ethiopian Horticulture Development Agency (EHDA). The government has also introduced attractive packages of incentives for both local and foreign investors engaged in horticultural ventures. These include such privileges as: provision of loans up to 70 percent of the investment capital; duty-free import of farm implements and equipment; and a five-year tax holiday to export-oriented growers. The government has also set a target of increasing production of fruits and vegetables from 1.28 million tons to 5.91 million tons by doubling the average productivity from 84 to 165 quintals per hectare and expanding land from 152.6 to 236 thousand hectares during the Second Growth and Transformation Plan (GTP II) period.

In order to achieve this ambitious plan, it is critical that two conditions must be fulfilled instantaneously. First, beside increasing production by the smallholders sector, large- and medium- size orchards producing tropical fruits have to increase substantially. Second both sectors need to be assisted by the research system to get access to improved technologies, agricultural innovation, information and knowledge so that they would be able to produce high- quality and volume of products that are competent in both domestic as well as export markets. For the research system to attune itself with such a vital role of developing the Tropical fruits sub-sector, EIAR has decided to develop this long-term research strategy traversing fifteen years.

The strategy is organized in six major chapters whereby this background section together with descriptions of the rationale, vision,

mission, goal and objectives constitute the introductory chapter 1. Chapter 2 provides an overview of the importance of tropical fruit crops in the Ethiopian agriculture; and food and nutrition security. Chapter 3 briefly discusses the situation analysis undertaken by assessing the internal environment as well as the external one involving all the key stakeholders to capture their reflections, concerns and desires. In chapter 4 are presented the critical issues that have been sifted out from the situation analysis and articulated as key challenges facing the tropical fruit crops research program. Chapter 5 discusses the actual strategic interventions to be pursued under the various thematic areas of the research to tackle the critical issues identified. Chapter 6 provides key elements of follow up documents that need to be worked out in the next steps as they are prerequisites for effective implementation of the strategy.

Rationale

Currently, the tropical fruits industry is not contributing to its level best albeit the potential it can have to: ensure food and nutrition security for millions of small-scale farming households; strengthen the opportunity for job creation and income generation; foster expansion of agro-industries, agri-business and import substitution; diversify the base for foreign earnings; and stabilize the macro-economy in general. Cognizant of its potential, the Government of Ethiopia has put in place favorable policy and regulatory frameworks that can be instrumental to propel the progress of the sub-sector which in turn would benefit small-scale and commercial growers, agro-industries and consumers of tropical fruits.

Therefore, the need for maximizing utilization of potential agro-climatic, physiographic and hydrologic conditions of the country to increase production, productivity and marketability of tropical fruit crops is a matter of urgency. In the present context though not only is wide the gap between what is available at research level and how much of that is being used by the farmer; but also are little the results attained thus far by the research system in comparison with the potential that could be realized from these crops. In order to create a condition where these divergent scenarios could converge and thus the commodities' potential could best be exploited, it is absolutely necessary to develop a well-defined and an all-inclusive research strategy representing and addressing the interests of all the key stakeholders involved in the value chains of the crops. Such a strategy not only creates a stronger cohesion and partnership among stakeholders but also serves as a roadmap to: guide the research program planning and implementation in line with the objectives and targets of GTP-II and that of EIAR; track records of results and lessons; and mobilize resources from national and/or international sources. It is with this rationale that the National Tropical Fruit Crops Research Program (NTFRP) - Team has developed this Research Strategy to achieve a common vision and objectives.

The NTFRP-Team has a strong conviction that a thriving future for the commodities can be achieved only if it involves meaningful collaborations between farmers, input suppliers, exporters, actors in agribusiness and agro-industry, traders, technicians, scientists, and

others engaged in the value chains. To this end, the research team has formulated a set of principles and values that reflect its vision, mission, goal and objectives underpinning its commitments and desires as indicated below.

Vision

The vision of the National Tropical Fruits Research Program is to become a leading agricultural program providing technological innovations and knowledge that can significantly contribute to improved livelihoods and environmentally sustainable development

Mission

The mission of the NTFRP is to generate, develop, adapt and promote competitive agricultural technologies, innovations, information and knowledge for improving productivity, nutritional quality and sustainable development of agriculture, agribusiness and agro-industry, supporting attainment of self-reliance and import substitution, and broadening the opportunity to exploit the potential export markets and income generations for households and the country

Goal

The goal of the NTFRP is to contribute to the EIAR's role towards the achievement of the sectorial objectives of ensuring food security; sustainable delivering of raw materials for agro-industries and import substitution; expanding the bases for the country to gain foreign earnings from agricultural exports, and increasing livelihood resiliency and environmental sustainability while reducing vulnerability to climate change

Objectives

The overall objective of the NTFRP is to increase the production, productivity and quality of tropical fruits through multidisciplinary and participatory research approach leading to increased share of tropical fruits in the national economy and advancement by understanding and applying new approaches in the whole set of the industry. Specific objects of the program, among others, include the following:

- To collect, introduce, characterize and develop varieties adaptable to different ecological and agronomic scenarios;
- To develop, adapt and promote improved agronomic and other technological packages suitable for tropical fruits;
- To develop, adapt and promote conventional as well as modern techniques and methods of efficient multiplication of planting material;
- To develop, adapt and promote integrated and sustainable pest (diseases, insects, nematodes, vertebrates and weeds) management packages and

- To develop, adapt and promote appropriate postharvest (maturity indices, harvesting, handling, storage, processing and utilization) management technologies.

Importance of Tropical Fruits

Fruit crops play a significant role in human nutrition, especially as sources of vitamins, minerals, and dietary fiber. For leading a healthy life style, an adult person requires to consume 400 grams of fruits and vegetables per day. However, the actual fruit consumption in Ethiopia is much far below this threshold; even in the urban areas where consumption of fruits and vegetables is supposedly reckoned to be common, only 1.4-2.3 % of the daily requirement is fulfilled. The fruit industry is relatively new to the agricultural system in Ethiopia and many of the crops have relatively been introduced only recently. More than 500 germplasm accessions of various fruit crops (introduced and locally collected) are under the custody of IBC and different research centers. Of these, banana represents 88 of the accessions, papaya- 115, pineapple- 6, date palm -314 (166 male and 148 female), passion fruit- 6 accessions. Cactus pear naturally exists in a wide range of diversity in the country.

Production of most of the tropical fruits is predominantly concentrated in the south and southwestern parts of the country; whereas production of date palm is currently located in some pocket areas of Afar, Somali, Gambella, Dire dawa, and Benshangul-Gumuz; and that of cactus pear in the north. Passion fruit though is given attention in GTP II, is by and large unknown to the majority of Ethiopians and its production is very limited to a single private company (Africa Juice Tibila S.C.). Hence, industrial processing of the fruit is the best way of making it more valuable both for the local and export markets. Out of the total area of 90,070.83 hectares being cultivated under fruit crops, banana accounts for 60% while papaya and pineapple account for about 3 and 1 percent, respectively. Annually more than 75 thousand tons of fruits are produced in Ethiopia where bananas alone account for ca. 70% of the produce while papaya accounts for 6%. Cactus pear is widely cultivated in Tigray and used for multiple of purposes, human consumption, animal feed, live fencing, bee forage, soil and water conservation, and carmine dye production. The fresh fruits and young *cladodes* (flattened-stem) are also processed into various recipes such as marmalades, jams, candies and mixed products along with other food ingredients. The total area covered by cactus pear in Tigray alone is within the range of 65,000 to 80,000 hectares. It also grows in North Wollo, Afar, Harari, Somali, Dire dawa and Bale; although it's economic value is not yet widely realized.

Fruit and vegetable industries in general have created job opportunities for more than 133 thousand people (70% of whom were female) in 2011/12 indicating the potential that the fruit industry could contribute in offsetting unemployment and poverty reduction in Ethiopia.

Although processing of fruits is so far limited to preparation of fresh juice for local markets, private companies like Africa Juice Tibila Share Company have started producing blended concentrates of passion fruit, papaya and mango for export markets in Djibouti, Sudan and Somalia. The potential export markets in United Arab Emirates, United Kingdom, the Netherlands, Belgium, Yemen, Saudi Arabia, and the Russian Federation are immense. However, inadequate production and quality standards are key bottlenecks limiting the development of the industries. More than 8.5 million USD is being spent for the import of processed fruit products and an additional two million USD for importing more than 2.5 thousand tons of dates.

Environmentally, fruit crops have the ability to modify the micro-climate in terms of temperature, relative humidity and wind speed among other things. On farmlands, they can also improve soil permeability, aggregate stability, water holding capacity and soil temperature regimes. Integrating fruit crops in rangelands can also increase total productivity, reduce sensitivity to short-term fluctuations of climatic conditions, spread ecological risks through species diversity and improve system sustainability. Furthermore, fruit trees can provide alternative land-use options and aid more sustainable farming systems.

Situation Analysis

Two categories of forces and factors influencing the conception, formulation, action and implementation of the strategy were analyzed as external and internal factors. The external factors (influences that are outside the research system) represent both the interests of stakeholders that the research should serve and the potential role that they can play to complement or synergize the research. Specific situations or stakeholders' interests that hold back research stride or the research falls short to positively respond to, represent the challenges (C); while those that create motivation for the research represent the opportunities (O). Therefore, the situation analysis of the external factors essentially examined Opportunities and Challenges (OC) presented from the existing Political /Policy /Legal, Economic, Educational, Socio-cultural, Technological/ Technical, and Environmental (PEST) perspectives of the factors. Almost all key stakeholders, notably the Ministries of: Agriculture and Natural Resources, Trade and Industries; exporters; private industries; farmers' unions; various relevant technical units of EIAR; the Regional Research Institutes and centers; and Higher Learning Institutions involved in Tropical Fruit Crops research have taken part in the process.

Analysis of the internal situation (influences that are outside the research system) was made by scrupulously examining whether or not there is the capacity within the research system that can readily be deployed by the team to deliver outputs or promptly respond to stakeholders' quests or challenges. While the presence of such a capacity denotes the strength (S) of the team; the capacity which is

required to deliver desirable outputs but falls short to exist represents the weakness (W). Therefore, analysis of the situation of internal factors examined Strengths and Weaknesses (SW) of the research team in terms of the existing resources (human, physical and fiscal); inter- and intra- disciplinary integrations, complementarities and synergies; availability of technologies, information and knowledge; and organization of internal system, and geographic coverage of the research program.

The results from the situation analysis were finally consolidated in a form of matrix whereby prevailing strengths, weaknesses, opportunities, and challenges (SWOC) were narrated with respect to their relevance to the various thematic areas that the research team is engaged in. From the situations narrated as such then were formulated the issues that the research system needs to address in the short-, medium-, and long- term plans. Experiences of other countries with respect to the level they have reached in research and development aspects of Tropical fruit crops were also examined to set a benchmark for the strategy.

Strategic Issues and Interventions

The major strategic thematic areas identified for the Tropical Fruit Crops Research Program include: Genetics and breeding; Crop protection; Agronomy and physiology; Technology multiplication; Irrigation and water management; Food science, postharvest management and value addition; Agricultural mechanization; Agricultural economics; Agricultural research extension and gender; GIS and Agro-meteorology; Capacity building; and Additional cross-cutting themes.

Most of the research issues identified to be addressed by the Tropical fruit crops research team are multi-institutional, multi-thematic, multidisciplinary, participatory, and need to be implemented in collaboration with farmers, extensionists and a wide range of other partners to be involved in the whole spectrum of the value chains. The research themes are built on the disciplinary as well as crosscutting themes briefly discussed hereunder. The strategic interventions proposed to tackle each of the issues identified for each theme, and need to be implemented during the next fifteen years on the: short-, medium- and long- term basis are presented in Table 1 following the narrations of the disciplinary and cross-cutting thematic areas.

Research Themes

Genetics and breeding

In the years ahead, the Tropical Fruit crops sub-sector foresees a steady demand for varieties with higher and more stable yields and acceptable quality. To keep pace with this demand, much of the focus will be on developing new varieties that are high yielding, adapted to a variety of environments, and resilient in the face of multiple stresses such as climate change, emergence of new pests and diseases, and other biotic and a biotic factors. The strategy will generally seek to accelerate crop improvement by using both conventional and

modern methods and technologies that make possible handling of large volumes of genetic material and select with greater precision. This will involve stronger integration of conventional plant breeding approaches with modern tools and methods of biotechnology.

Crop protection

To make crop production more eco-efficient is to achieve yield stability and reduce the chances of crop failure due to diseases and other pests, whose dynamics are shifting as a result of climate change. To this end, the research will focus on both host plant resistance and biological control with greater emphasis to integrated approaches of controlling diseases, insect pests, weeds and vertebrate pests through Integrated Pest Management (IPM) systems.

Agronomy and physiology

Keeping the principle of eco-efficiency, the agronomy and crop physiology endeavor will focus towards developing improved crop and soil management practices that open the way for optimal expression of genetic potential of varieties and enhancing the physiological and agronomic efficiency of Tropical fruit crops.

Technology multiplication and seed research

The core of research activities envisioned by the technology multiplication and seed research component of the strategy will be to: identify key problems associated with producing sufficient quantity and quality of initial material by generating basic information that would help to develop technologies addressing the challenges; adopt advanced tools of Tissue culture for developing disease-free planting material of Tropical fruit crops; identify and adopt good practices of technology multiplication for large-scale production of the crops; and devising an internal system whereby expeditious multiplication of high-quality planting material would be effected in order to meet ever growing demand.

Irrigation water and nutrient management

Development of water-efficient management practices including micro-irrigation, fertigation; irrigation scheduling, etc. constitute arears of intervention related to production of Tropical fruit crops as they form an integral component of league of crops that are best fitting for production of high-value crops under irrigation conditions.

Food science, postharvest management and value addition

The Tropical fruit crops have a great deal of potential in the food industry. It is therefore, essential to work on chemical characterization

and profiling of the available varieties and eventually the genepool for nutritional as well as industrial values. It is also critical to develop recommendations on post-harvest technologies that would improve the shelf life of the crops. Establishing alternative ways of processing the produce in view of increasing their shelf life will also open up a new vista of value addition and product diversification and thus better market opportunities for producers and options of choices for consumers.

Agricultural mechanization

The main challenges associated with agricultural machinery and post-harvest handling is the fact that producers in Ethiopia had little opportunity to employ small-scale farm implements, water pumps for irrigation, means of transportation, and storage structures that are appropriate for Tropical fruits. Both pre- and post- harvest operations are done manually and losses in both quantities and qualities associated with manual practices are often appalling. It is therefore, imperative to consider this field of research in this research strategy.

Agricultural economics

Agricultural economics is among the core themes of research as it plays a vanguard role in linking the biological sphere of the research and the economic validity of the results when actually being implemented by the farmer or other targets in the recommendation domains. Furthermore, it has also a key role to play in addressing policy issues that are instrumental in developing and promoting efficient, functional and sustainable value chains of the Tropical fruit crop commodities.

Agricultural extension and gender

The agricultural extension and gender component of the research brings in stakeholders together to formulate relevant research agenda as it does also take out promising research results to the demonstration and extension processes. Notwithstanding the role the extension component plays in addressing the social aspects of the research, it is the main channel for the two-way flow of information between the research system on one hand and the end users of the research results on the other. Therefore, addressing issues related to socio-economic and research extension in the strategy is vital to attain the successes that the research team envisages. It will also be crucial to address issues related to gender equality and inclusiveness of the research process in general through this component.

GIS and agro-meteorology

In formulating strategic interventions to be harnessed for achieving the objectives stipulated from the outset, it will be given due attention to GIS and agro-meteorology for better understanding of the dimensions of local climate and farming systems (physical climate, social, economic, farming systems, etc.) for targeting and developing the right technology for the right environment.

Capacity building

Two important issues were identified under this topic: the need for strengthening the capacity of the research team; and the stakeholders involved in the Tropical fruit crops value chains in general need to have a strong, functional, influential and sustainable forum that will shape up the future of the research, production, processing, trade, and consumption of the commodities.

Crosscutting themes

Gender: The role of women in the agricultural system is critical as women contribute 70 percent of farm labour at harvesting and in post-harvest activities. But women farmers have only limited access to resources, services, land and credit. Unequal gender relations often make women more vulnerable to the effects of poverty, land degradation, and climate change. If the gender gap were eliminated, FAO asserts that total agricultural output would increase. Cognizant of this, the strategy upholds integration of gender concerns into research objectives, technology development, extension, and evaluation frameworks.

Climate change: In Ethiopia, climate change is already having an impact on the livelihoods of different communities in different corners of the country. Therefore, the research strategy will place due considerations to availing technologies that would help actors in the value chains of Tropical fruit crops to respond to climate change through adaptation and/or mitigation approaches.

Knowledge management (KM): Through KM interventions aided by new information technologies, it is possible to help improve smallholders' access to resources that help them improve their farm productivity and competitive ability. KM will also help to create research products in a more collaborative manner that makes them more suitable for diverse audiences. For this purpose, the research team will make results more readily available, spearhead formations of multi-stakeholder platforms that facilitate interaction and promote learning for change, mentoring, and networking.

Strategic Interventions

Table 1 Strategic interventions planned to address critical issues facing the National Tropical Fruit Crops Research Program in the short-, medium- and long- terms

Thematic areas	Strategic Interventions		
	Short term (5 years)	**Medium term (10 years)**	**Long term (15 years)**
5.2.1 Genetics and breeding			
Limited germplasm and narrow genetic base; sub-optimal quality and productivity; inadequate system of germplasm maintenance; weak integrations and collaborations	• Collect and characterize additional germplasm materials from within the country (date palm, passion fruit and cactus pear); • Introduce additional royalty-free improved germplasm materials from outside sources (banana, papaya, pineapple, date palm, passion fruit and cactus pear); • Introduce additional varieties with desirable traits of yield and quality; • In collaboration with IBC, develop well equipped field gene banks for conservation of indigenous and exotic tropical fruit germplasm across national and regional research centers; • Strengthen integration and joint variety development work with relevant research disciples (crop protection, irrigation, soils, socio-economics, food science and postharvest,)and • Establish partnership with regional research institutions for germplasm exchange/introduction (East African countries).	• Broaden genetic variability (using mutation breeding, hybridization, biotechnological tools,); • Screen and develop varieties that are of good adaptability to different AEZs, fruit yield and quality, and resistance to biotic and abiotic stresses (pests, salinity, heat, cold, drought,.); • Develop varieties with specifically desirable traits such as yield, market/consumer preferences and quality suitability for agro-processing; • In collaboration with IBC, adapt and develop *in-vitro* and cryo-conservation facilities and protocols for different tropical fruit crops; • Strengthen integration and joint variety development work using more advanced techniques and • Establish partnership with international organizations for germplasm exchange/introduction (IITA, BARNESA, Bio diversity, .	• Strengthen activities and approaches of broadening the genetic variability through crossing, mutation-breeding, hybridization and biotechnological tools; • Strengthen development of varieties with specifically desirable traits such as yield, market/consumer preferences and quality suitability for agro-processing; • Strengthen adaption and development of *in-vitro* and cryo-conservation facilities and protocols for different tropical fruit crops and varieties; • Strengthen joint variety development and use of more advanced technological packages with relevant research disciples and • Strengthen the regional and international partnership for germplasm exchange/introduction.
5.2.2 Crop protection			
Limited information on outbreak, biology, epidemiology and ecology of	• Assess and determine major pests (diseases, insects, vertebrates, weeds) of tropical fruits across different AEZs;	• Generate information on molecular and serological disease diagnostic techniques;	• Strengthen generating information on molecular and serological disease diagnostic techniques;

major pests; lack of IPM; limited information on biological/botanical and agro-chemical pest management components; premature decline of orchards and rapid postharvest fruit deterioration	• Generate information on outbreak, epidemiology, biology and ecology of major pests of tropical fruits across different AEZs; • Identify key pests (such as cochineal, bacterial wilt, mealy bug, etc.) and adapt/develop IPM packages and standardize control measures; • Introduce, test and register environment-friendly agrochemicals and biological / botanicals against major pests and • Identify specific causes and develop effective control measures against: crown rot, cigar end rot, black spot, *Fusarium* wilt, mildews, bugs, *Phytophathora*, mites, viruses, nematodes, .	• Develop more advanced IPM packages and standardize control measures; • Develop environment-friendly agrochemicals and biological / botanicals and their application methods against major pests and • Strengthen the development of more advanced and effective pest insect pests, diseases, mites and nematodes) control measures.	• Strengthen the development of more advanced IPM packages and standardizing control measures; • Strengthen the development and use of environment-friendly agrochemicals and biological / botanicals against major pests and • Strengthen the development of more advanced, refined and effective pest control methods.
5.2.3 Agronomy and physiology			
Lack of packages of specific agronomic practices; inadequate technologies for organic products and intensive farming; and knowledge and information on responses to variables of production factors; and limited technologies of tree management	• Adapt and develop appropriate orchard management practices specific for different fruits (passion fruit, cactus pear, etc.) and AEZS; • Develop appropriate nursery management techniques for propagation of healthy and vigorous planting materials (date palm, cactus pear, ; • Adapt and develop appropriate agronomic packages for organic production (INM, bio-fertilizers, cropping systems, etc.) that satisfy niche-market standards; • Adapt and develop appropriate agronomic packages (planting densities, cropping systems, irrigation, fertilization, crop protection, etc.) for intensive commercial orchards; • Identify causes of physiological disorders and develop control measures and • Develop and standardize fruit tree	• Develop more advanced agronomic packages (INM, plant density management, flower and fruit thinning, controlled and hand pollination, pruning and training, sucker management, ; • Develop more advanced agronomic packages for organic and intensive commercial production; • Determine phenological characteristics and their relationships with fruiting seasonality, productivity and quality and • Develop more advanced techniques of fruit tree management.	• Strengthen development of more advanced and refined agronomic packages; • Strengthen development of more advanced agronomic packages for organic and intensive commercial production; • Determine physiological factors causing alternate bearing, flower abscission and fruit drop in cactus pear, date palm, papaya, and passion fruit and • Strengthen development of more advanced and refined techniques of fruit tree management.

	management techniques (sucker management, pollination, flowering fruiting, pruning, training, .		
5.2.4 Technology multiplication and seed research			
Inadequate standards, techniques and protocols; and lack of good-quality initial planting materials	• Adapt and develop standardized conventional and micro-propagation techniques and protocols; • Multiply good-quality initial planting material of tropical fruits using conventional and *in-vitro* mass propagation techniques.	• Multiply good-quality initial planting material of tropical fruits using conventional and *in-vitro* mass propagation techniques	• Strengthen multiplication of good-quality initial planting material of tropical fruits using conventional and *in-vitro* mass propagation techniques
5.2.5 Irrigation water and nutrient management			
Limited irrigation management technologies; and inadequate water-harvesting and saving irrigation /fertigation technologies	• Adapt and develop appropriate technologies for crop specific water requirements and irrigation scheduling across different AEZs; • Develop water-efficient irrigation technologies for different AEZs and • Adapt and develop appropriate water harvesting (seasonal run-off, roof water, etc.) and water-efficient irrigation technologies (drip, sprinkler, pitcher, basin, fertigation, etc.) across research centers.	• Develop more advanced technologies for crop specific water requirements and irrigation scheduling across different AEZs; • Develop and refine more advanced water- harvesting and efficient irrigation technologies for different AEZs.	• Strengthen development of more advanced technologies for crop specific water requirements and irrigation scheduling appropriate for different AEZs; • Strengthen development of more advanced water- harvesting and efficient irrigation technologies for different AEZs.
5.2.6 Food science, postharvest management and value addition			
Limited information on quality standards, nutrient compositions, nutritive values, etc.; and postharvest management technologies	• Assess the causes and determine extent of postharvest losses of tropical fruit crops across different production areas and market outlets; • Adapt and develop improved postharvest management technologies (harvesting, storage, handling, packaging, processing, and • Study the suitability of fruit species and varieties for agro-processing and market/consumer. demands	• Adapt and develop appropriate technologies for value added products; • Refine and develop more advanced postharvest management technologiesand • Establish the conditions dictating suitability of fruit species and varieties for agro-processing and market/consumer demands.	• Develop appropriate crop and product specific (fresh and processed) postharvest management technologies (maturity indices, harvesting, storage, handling, packaging, processing;Refine and develop more advanced postharvest management technologies and • Refine facts established on the conditions dictating suitability of fruit species and varieties for agro-processing and market/consumer demands.

5.2.7 Agricultural mechanization			
Inadequate pre- and post-harvest farm machinery and implements	• Listing research-developed and locally available small-scale technologies, evaluate and promote those appropriate for pre and post-harvest management of tropical fruits; • Adopt and adapt additional state-of-the-art agricultural mechanization technologies appropriate for small-scale farmers growing tropical fruits.	• Avail pre- and post-harvest mechanization technologies through adaptation to suit existing situations.	• Avail more advanced and appropriate pre- and post-harvest implements through adaptation to suit existing situations; • Adapt state-of-the-art technologies of pre- and post-harvest management and avail those which can make the country competent in the world market.
5.2.8 Agricultural economics			
Limited information on value chains; marketing farming systems characterization and diagnostics; and issues of technology adoption and impacts	• Conduct crop-specific analysis of value-chains and determine market efficiencies in different tropical fruit-growing parts of the country; • Develop systems of generating and communicating market information to different actors in the value chains of tropical fruits; • Undertake studies on characterization and diagnosis of farming systems incorporating tropical fruit crops and • Undertake studies on the rate of adoption and impacts of technologies of tropical fruits (bananas, papaya and pineapple).	• Strengthen the study on the dynamics of value chains of selected tropical fruits; • Strengthen the systems developed to generate and communicate market information to different actors in the value chains of tropical fruits; • Strengthen and expand the scope of studies on characterization and diagnosis of farming systems incorporating tropical fruit crops and • Strengthen studies on the rate of adoption and impacts of technologies of tropical fruits (bananas, papaya and pineapple).	• Strengthen the study on the dynamics of value chains of selected tropical fruits; • Strengthen the systems developed to generate and communicate market information to different actors in the value chains of tropical fruits; • Strengthen and expand the scope of studies on characterization and diagnosis of farming systems incorporating tropical fruit crops and • Strengthen studies on the rate of adoption and impacts of technologies of tropical fruits (bananas, papaya and pineapple).
5.2.9 Agricultural extension and gender			
Inadequate promotion and popularization of technologies; inadequate information on participatory technology development, evaluation, and adoption; limited gender mainstreaming in the processes of development and adoption of technologies, and production,	• Create awareness and identify technology-cum-information dissemination and popularization methods enhancing production and consumption of tropical fruits in both rural and urban areas; • Establish a network of platforms serving various interests of stakeholders in major fruit growing areas of the country; • Adapt and disseminate best-bet practices on	• Strengthen methods of awareness creation and technology-cum-information dissemination and popularization enhancing production and consumption of tropical fruits in both rural and urban areas; • Strengthen networks of platforms serving various interests of stakeholders in major fruit growing	• Strengthen methods of awareness creation and technology-cum-information dissemination and popularization enhancing production and consumption of tropical fruits in both rural and urban areas; • Strengthen networks of platforms serving various interests of stakeholders in major fruit growing

marketing and utilization of tropical fruits	successful household-level establishment of cactus pear orchards and cactus moth and cochineal control methods in dryland areas and • Mainstream gender in the processes of development and adoption of technologies; and production, marketing and utilization of tropical fruits.	areas of the country; • Strengthen dissemination of best-bet practices on successful household-level establishment of cactus pear orchards and cactus moth and cochineal control methods in dryland areas and • Strengthen mainstreaming gender in the processes of development and adoption of technologies; and production, marketing and utilization of tropical fruits.	areas of the country; • Strengthen dissemination of best-bet practices on successful household-level establishment of cactus pear orchards and cactus moth and cochineal control methods in dryland areas and • Strengthen mainstreaming gender in the processes of development and adoption of technologies; and production, marketing and utilization of tropical fruits.
5.2.10 GIS and Agro-meteorology			
Lack of information on spatial suitability, climate characterization and modeling and adaptation responses	• Conduct spatial suitability analyses and develop suitability map of tropical fruit crops as distributed across the various AEZs; • Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall in meeting crop water requirements under rain-fed system across AEZs.	• Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall and irrigation water requirements under irrigated conditions; • Develop integrated management practices fostering crop adaptation to increased heat load in tropical fruit plantations.	• Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall and irrigation water requirements under irrigated conditions and • Develop integrated management practices fostering crop adaptation to increased heat load in tropical fruit plantations
5.2.11 Capacity building			
Inadequate resources • Human • Physical • Finance	• Strengthen the number of research and technical staff through recruitment; • Improve technical cunning of the research staff through short- and long-term trainings tailored to upgrade research skills and qualifications; • Strengthen dexterity of researchers and technicians in application of specific topics like *propagation techniques, orchard and postharvest management, molecular breeding, in-vitro conservation, protection,*	• Provide tailored and hands-on short-term trainings on *molecular breeding, in-vitro conservation, postharvest handling, value chain analysis, quality assurance for planting materials, modern technologies of data collection and sharing,* ; • Upgrade the existing and establish additional modern irrigation infrastructure and propagation	• Strengthen medium- and long -term trainings as well as experience-sharing visits on more advanced and up-to-date technologies; • Establish additional research centers and sub-centers across un represented AEZs; • Upgrade the existing and establish modern irrigation infrastructure, green houses and lath houses at the remaining fruit research centers field

	etc. through exposure and experience-sharing visits; • Upgrade the existing and establish additional research laboratories (biotechnology, postharvest and nutrition, soils, plant protection); • Upgrade existing offices, libraries, ICT units, farm machinery, and field vehicles; • Avail necessary field vehicles and farm machinery in each centers implementing research on tropical fruits and • Allocate sufficient budget for research and capacity building and improve efficiency of utilization.	structures (*green houses, shade houses, lath houses, etc*.) at the main centers; • Set up virus-indexing facilities and services across major research centers; • Mobilize additional project grants from resource partners and international research institutions and • Mobilize additional support from national horticultural institutions and large scale commercial fruit farms.	vehicles; and farm machineries for coordinating centers; • Strengthen mobilization of project grants from partners and international research institutions and • Strengthen mobilization of support from and partnership with national horticultural institutions and large scale commercial fruit farms.
5.2.12 crosscutting themes			
Gender	Organize gender disaggregated data for technology dissemination, adoption and impact of technologies; and in the course of technology demonstration, popularization, and training ensure that all female-headed households and at least 30% of beneficiaries to be women from male-headed households		
Climate change	Develop research programs that would adequately address the challenge to increase resilience of vulnerable communities		
Knowledge management	Consider modern facilities of ICT instrument in knowledge and information transfer and sharing processes		

The Next Steps

Following the approval of the strategy document by the top management of EIAR, it is essential to prepare the implementation plan, without which this strategy is not going to reach fruition. The implementation plan document will be developed using a common Guideline adopted by the EIAR Planning, Monitoring and Evaluation Directorate to provide guidance to research teams develop implementation plans. The implementation plan will thus come out as Volume II of the research strategy, which will serve as the blueprint to guide the National Tropical Fruit Crops Research for the next fifteen years (2016-2030). The major contents of the implementation plan will revolve, among others, around the following topics:

- Develop implementation plan;
- Develop monitoring and evaluation plan;
- Develop impact assessment plan and
- Develop reassessment plan for the strategy.

Warm Season Vegetables Research Strategy

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Introduction

Ethiopia is endowed with diversified agro-ecological conditions favorable to produce majority of warm season vegetables such as tomatoes (processing, fresh market and cherry), *Capsicums (*hot pepper, sweet pepper and chilli), snap beans, cucurbits, egg plant, amaranths and okra. Smallholder farmers and some commercial farms produce different vegetables in wide altitude ranges (up to 2500 m.a.s.l.) of the country under rain fed and irrigated conditions. The country produces about 852,303.89 metric ton of vegetables from a total of 6,789,289 ha which is 1.43% of the total area covered by all crops at national level (CSA, 2013). Out of the 5.37million ha of potentially irrigable land on which fruits and vegetables could be produced only about 250,000ha of the potentially irrigable land is currently under vegetable cultivation.

Vegetable crops can generally be a very important source of vitamins, minerals and proteins to a country like Ethiopia where the people experience malnutrition due to heavy dependence on cereals. Vegetables primarily contribute to alleviating health problem by providing vitamins, minerals and hence improving the nutritional quality of the Ethiopian diet. Several studies have revealed that vitamin A deficiency is a major public health problem in Ethiopia. Ethiopia can be considered as 'at risk community' country, where less than 75% of pre-school age children consume vitamin A rich foods at least three times a week.

There has been a steady increase in the demand of different vegetable crops for export and processing purposes. Above all, the country is also strategically located for export of fresh produce to neighboring countries like Sudan, Somalia and Djibouti), the Middle East and the EU-markets. Export of fruits and vegetables has been increasing through years from 2002/03 to 2014/15 from 9.6 to 47.5 million USD, respectively)

Currently the horticulture industry in general and warm season vegetable sub-sector in particular is lagging far behind in providing enough nutrition and generating sufficient income from export. Small scale farms, which produce the bulk of vegetables for local consumption, are not in a position to produce vegetables to the standard satisfying the export market. This production practice was characterized by low input, poor water management, high pest and disease damage, high post-harvest losses, poor organization, and uncertain markets.

To date, efforts have been made to improve the production system through availing improved packages of production technologies. In effect, varieties were released and agronomic practices were recommended for major vegetable crops tomato, Alliums and Capsicums. As result, growers have been motivated to the production of these crops. However production, productivity and product quality are still far

lower than other countries. Seasonality of production and market problems coupled with high postharvest losses are still major challenges of the sub-sector. On the other hand, limited research focus, lack of knowledge and skill by growers and traditional consumption habit in the country in general have led to restricted production both in quantities and types of vegetable produce. Despite huge potential in producing wide range of vegetable crops throughout the year, availability and quantity of production is yet dependent on season and limited to certain crop types and area. Availability of packages of technologies for different production systems including irrigated and rain fed in various agro-ecological areas are limited. Due to the abovementioned problems and accompanying under development of the sub-sector, export demand for warm season vegetable crops from the non-agricultural Middle East and some neighboring countries have been fulfilled by imports from as far as the South American countries.

Generally, the sub-sector is unable to meet the existing increasing local demand for vegetables, let alone to compete for export market. During the rainy season, for instance, onion bulb for food is imported from Sudan. Likewise, fresh tomatoes are not available during the rainy season in many areas of the country and supermarkets are full of tomato pastes imported from abroad.

It is clear that with the existing situation, the sub-sector is not able to compete with poor quality products with South America, North Africa and Far East. However, several measures have been taken by the Ethiopian government including investment privileges of provision of 70% of the investment capital, duty-free import of farm equipments and a five year tax holiday to export oriented growers. Consequently, agro-processing companies such as Ethio-vege fru PLC, Ethio-rose PLC, Genesis Farms; etc are producing some high value vegetables for export and local market. Moreover, some flower growers began to diversify the greenhouse vegetables with bell pepper, chilies, tomatoes and snap beans.

The government of Ethiopia has set an ambitious second round five-year growth and transformation plan (GTP II) to bring about transformation in the productivity and production of high value market oriented vegetables. Furthermore, development of climate smart production technologies for sustainable farming and food security are key issues in GTP II.

To improve productivity and volume of production as planned in GTP II, appropriate packages of technologies are required in which the role of research is crucial. While multiplying, promoting and disseminating technologies developed so far, relentless efforts need to be exerted to adapt and develop technologies suitable to address existing challenges as well as emerging issues reflected in GTP II.

In the process, innovative approaches in advancing the benefits of vegetable crops, particularly under the enhanced climate variability and change under the theme climate smart agriculture (CSA) need to take the highest priority. Examples include protected culture, fertigation

and organic farming and many more others. The experiences elsewhere in the Far East, North Africa and neighboring countries such as Kenya have shown that protected culture using tunnels and greenhouses have revolutionized horticultural production and resulted in high value products throughout the year. Therefore, developing this sub-sector through building on the efforts made in the past and designing a clear and long term research and development strategy is vital for this country to effectively utilize the different advantages of these crops in the future.

Rationale for the Strategy

With the growing irrigated agriculture and agricultural development led industrialization of the country, there is a very high prospect for the development of the sub-sector as a source of income, nutrition, employment, hard currency earning and raw material for agro-processing industries. In addition to striving to secure self sufficiency in food and nutrition, emphasis in GTP II has been given to market oriented high value warm season vegetables. Local and export demand for vegetable is increasing from time to time. However, there are lots of technological gaps that need to be tackled. Strategic research approach is thus required to support the sub-sector with innovations so as to boast production, productivity and quality of produce. The need for research strategy based on the priority developmental constraints is indispensable in order to increase the contribution of the sub-sector in improving the growers' income and subsequently improve the living standard of the people and contribute to economic growth of the country in a sustainable manner. The strategy will thus serve to guide and coordinate research activities in the next fifteen years facilitating adoption and generation of appropriate technologies, knowledge and information aiming to meet the objectives of agricultural development plan. A strategic research approach is required primarily to:

- Alleviate the existing challenges of warm season vegetable production, productivity and product quality;
- Optimize utilization of available opportunities for vegetable production, utilization , processing and local and export marketing;
- Mitigate adverse effects of climate change and other emerging issues and
- Further developing the sub-sector through technology based production systems of protected culture, drip irrigation and fertigation

Vision

To be a leading program in warm season vegetable technology innovations; availing high quality technologies, information and knowledge that would contribute to economic growth, improved livelihoods and sustainable development.

Mission

Develop, adopt and disseminate vegetable technologies, information and knowledge to increase production, productivity and quality under small scale and commercial production at different AEZs satisfying local and export market, and processing industries

Goal

To increase production, productivity and product quality of warm season vegetable crops under different production systems (irrigated, rain fed, protected and organic farming systems) in both smallholder as well as commercial growers.

Objectives

- Adapt, develop and promote improved technologies, knowledge and information that increase production and productivity and quality of vegetable produce to satisfy the standards of both domestic and international markets
- Coordinate research activities on warm season vegetables being undertaken by various research partners and play key role in building technical capacity of farmers and other stakeholders

Guiding Principles

In order to accomplish its mission and fulfill its objective, the warm season vegetable research program has established a set of guiding principles and criteria for selecting research projects and major activities for the implementation of the strategy. The program will, accordingly, be guided by the following basic and unwavering principles:

- Change in attitudes and perceptions on the part of researchers and support staff;
- Development and expansion of external and internal linkages;
- Team approach and partnership (public and private);
- Loyalty and respect to diverse client needs;
- Responsibility and accountability;
- Environmental consciousness; and
- Inclusiveness(men, women and youth).

Importance of Warm Season Vegetable Crops

Agriculture

Agriculture is the main stay and contributor to the national economy both in terms of income, employment and generation of export revenue and contribution to 44% to GDP has remained very high. Among the sub-sectors of agriculture, crop production is major contributor to GDP accounting for about 28 % in 2012,. Irrigated agriculture has been identified as an important tool to stimulate economic growth and rural development and considered as a cornerstone of food security and poverty reduction in Ethiopia. According to IWMI report (2009) an average income of US$323/ (ha) was generated under smallholder-managed irrigation systems compared to an average income of US$147/ha obtained from rain fed systems which 219.7% higher than the gross margin obtained from rain fed agriculture.

The government of Ethiopia has set GTP II for five years which aims to boost the production of vegetable from 959.54 thousand tones to 2.34 million tones through increasing productivity from 105.6 to 190.8 t/ha. The increase in production is hoped to be achieved through increasing productivity through improved vegetable production technologies and expanding production into the country's 5.37million ha of potentially irrigable land, of which only 250,000 ha is currently cultivated.

Agro-ecology and farming systems

Ethiopia is endowed with favorable agro-ecological conditions to cultivate many of the warm season vegetables crops in the lowlands (<1500 meters above sea level) and midlands (1500-2200 masl). Smallholder farmers and some commercial farms produce different vegetables under rain fed and irrigated conditions. The irrigated vegetable production system is increasing because of increasing commercial farms and development of small scale irrigation schemes.

Major production agro-ecological zones (AEZs)

There are different AEZs with adequate irrigation water, favorable climatic conditions and high potential for the development of the sector.

Hot to worm and low land plains (A1)

This area covers about 30% of the country, which includes some parts of Oromiya, Afar, Somalia administrative regions. It has low rainfall and various soil related constraints. It is generally favorable for production of different irrigated vegetables. It represented by Werer Research Center.

Tepid to cool semi arid and mid high land (SA2)

It is dominated by the rift valley lakes and small streams. It has low rainfall, dry weather and diverse soil related problems. It covers about 0.28% of the country and has high potential for the vegetable industry. Different warm season irrigated vegetables are produced. There are well established irrigated farmers plots, large scale commercial production of diverse mixed vegetables for the local and export market. This agro ecology will be covered by Melkasa Research Center.

Tepid to cool sub-humid mid high land (SH2)

It covers 7.6 % of the country, which includes the mid highland of Southern Ethiopia, which is traditionally a horticulture belt and North Harerge region. Home gardening is a traditional way of providing food for the family in the region. It is represented by Bako, Awassa and Areka Research Centers.

Tepid to cool sub moist mid high land (SM2)

It covers Tigray, Northern and Easter Shewa and North Wollo. It covers wide climatic regions and is about 0.42% of the country. It is represented by Mekelle, Sheno, Debre Zeit and Melkasa Research Centers.

Genetic resource

Diverse and readily accessible genetic resources are vital for any crop improvement program oriented toward high and stable yields and specific consumer preferences then will contribute to food security and a diverse diet for the ever increasing global population. The World Vegetable Center Gene bank maintains the world's largest public vegetable germplasm collection of more than 61,000 accessions from 155 countries, including about 12,000 accessions of indigenous vegetables.

Ethiopia is well known for its diversity of indigenous plants, including vegetables of Ethiopian mustard (Kale), pumpkin, chilli and okra. Okra (Abelmoschus app.) has high diversity in Ethiopia and it is an important vegetable in some parts of the country particularly in the western lowlands (550 to 650 masl) regions. In addition to the cultivated species, the distribution of other two species A. manihot and A. moschatus are reported recently.

On the other hand, poor germplasm base for exotic vegetable crops such as onion, tomato, *capsicums,* snap bean, cucurbitaceous and egg plant and the absence of strong collaboration with international institutions for germplasm exchange have contributed to sluggish development in cultivar development. Since germplasm is the base for cultivar improvement, it is crucial to wisely utilize local genetic resources and also enrich the base through international collaborations and various techniques of variability creation and collection. Numerous economically important vegetables are exotic types and thus research depends mainly on importation of germplasm from different international sources. Thus, there is a need for source of germplasm of these vegetables to improve variety development in the country and compete in the international market. Selection of better parental material in response to challenges of biotic & abiotic stresses and related climate changes are crucial to undertake crossing programs. In addition to devising different strategic options to strengthen international and national collaborations for germplasm exchange, wise exploration of local genetic resources, variability creation via different techniques and technology shopping are therefore priority of priorities.

Production and Productivity

Globally, vegetable production has grown intensively especially on a per capita basis, which has increased 60 percent over the last 20 years. Average vegetable production between 2001 and 2010 was 54 percent higher than the average of the preceding decades (1991-2000). Vegetables cover 1.1 percent of the world's total agricultural area, in which Europe and Central Asia contributing with 12 % of the total global area, and with 14 % of production.

Vegetable production is an important economic activity in Ethiopia, ranging from gardening smallholder farming to commercial private farms. Vegetable crops occupied < 1% and 1.65 % of the total area and production covered by all crops at national level, respectively. A total of more than 0.95 million tones of vegetables were produced from 154,621.3ha hectares creating means of livelihoods for over 8.73 million households. Moreover, vegetable production under commercial farms has also increased from 108.6 thousand tons in 2010 to 221.1 thousand tons in 2015 while productivity and area increased from 34.3 to 35.2 tones and from 9711.2 to 108631ha, respectively, during the same period. The commercial production is concentrated in the rift valley areas of Ethiopia, due to availability of irrigation facility, accessibility and closeness to agro-processing industries.

Warm season vegetable crops of economic importance that largely produced in Ethiopia include Capsicums, onion and tomato and green beans whereas okra, paprika, egg plant and cucumbers have recently emerged as an important export vegetable. Indigenous vegetables such as okra, pumpkin, jute mallow and others are part of the culture of the Ethiopians and contribute to food security and survival to the rural population during adverse drought.

Three major warm season vegetable crops viz. hot pepper, tomato and onion dominate small scale vegetable production in the country with hot pepper (dry and green) occupying 78% and of the total area coverage by the three vegetable crops (126,143.31 ha) followed by onion (18%) and tomato (4%). In terms of volume of production, however, onion occupies the highest share of 49.26 % followed by hot pepper (dry and green) 44.3 % and tomato 6.6%. Although, other warm season vegetable crops such as watermelon, melon, squash, cucumber, pumpkin, okra, egg plant and snap bean are produced as an important export vegetable in the country, the area coverage of these vegetable crops is minimal and often reliable production data are not available.

Total production of tomato, pepper (dry and green) and onion has increased more than two fold with the maximum growth recorded in pepper. The area coverage increments are 133.7, 181.8, 262.9 and 4148% for tomato, dry and green pepper and onion respectively whereas, changes in total production for these vegetable crops is 55.9, 191.6 and 106.5 % respectively between 2004 and 2015.

The total area coverage and production of tomato, dry and green pepper and onion did not show a clear increasing trend; rather oscillated up and down between minimum values of 74860 ha and 379854.8 ton in 2004 and maximum value of 715116.4 ton and 176194 ha in 2012 and 2013 (Figure 1). The increase in production trend of these vegetables in some of the years such as between 2010 and 2012 (Figure 1), however, was attributed mainly due to expansion of irrigated land.

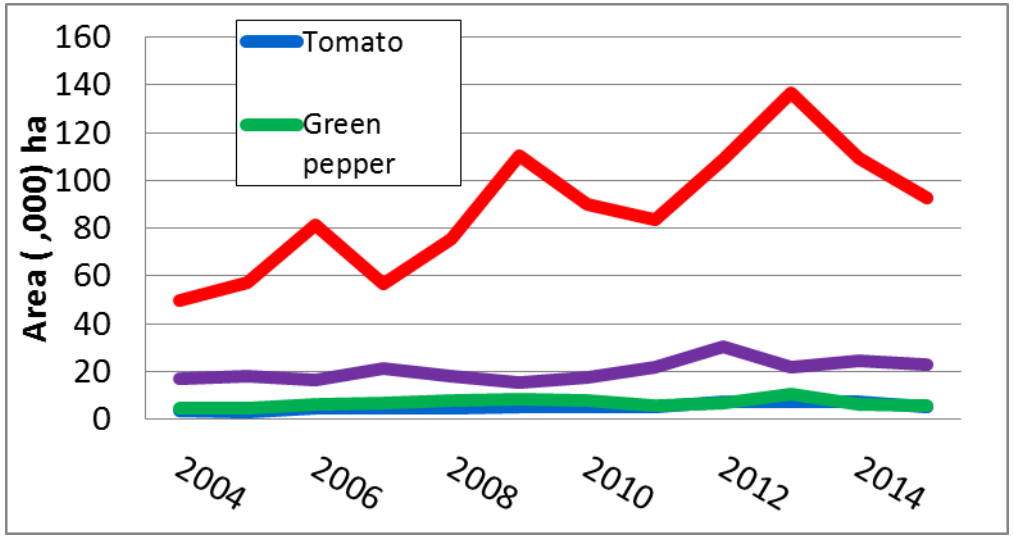

Figure 2: Total area coverage and production of tomato, pepper (dry and green) and onion (Source: CSA, 2004-2015)

The productivity is still lags behind that of major producing countries such as China and India (Table 1) which fails to supply the population with the required income, employment, export, agro-processing and nutrition. Moreover, the national yield of these vegetables failed to attain what can be attained under research managed field; for example the yield gap between maximum national and research managed yields of tomato and onion is more than 200%.

Table 5. Comparison of productivity (t/ha) of major vegetables of Ethiopia with major producers and the World average

Crop	Countries				World average
	Ethiopia	China	India	Kenya	
Onion	10.13	22	16	11.2	19.4
Tomato	6.11	50	20.7	20.5	33.8
Pepper(dry)	1.85	6.8	1.7	1.2	1.8

Food and Nutrition

Vegetables are the major sources of vitamins and minerals, trace elements, dietary fiber, protein and add flavor to diets and provide nutrition to growers and consumers. Although minerals are less bioavailable in plant foods, vegetables provide a large proportion of minerals such as iron and calcium consumed in rural populations in developing countries. Vegetables provide antioxidants such as vitamin A, C and E that are important in neutralizing free radicals (oxidants) known to cause cancer, cataracts, heart disease, hypertension, stroke and diabetes. They are also the most important sources of vitamin A, a nutrient important for several metabolic activities in the body, in addition to its role as antioxidant. Despite the recorded increase in some major vegetables, the production of vegetables is not yet sufficient to adequately supply the population with the required nutrition.

Cognizant of these facts, FAO/WHO recommends 400 gram of fruits and vegetables per day or alternatively five servings a day; at least two servings of fruits and three servings of vegetables (WHO, 2003). However, the daily per capita consumption of vegetables and fruits in Ethiopia has been less than 100g which is less than a quarter of the recommended consumption. Hence, deficiency of vitamins has been the major public health problem in Ethiopia.

Compared to other food group nutrient profiles, vegetables provide the nutrient characteristics that most consumers perceive as health promoting. Vegetables contain no cholesterol, very little fat, sugar, and sodium, yet provides concentrated sources of many vitamins and minerals. Table 3 presents representative nutrient ranges and means for commonly consumed vegetables in Ethiopia.

Table 6. Vegetable Composition based on 100 grams (g) of Edible Material as Raw or Minimally Prepared for Consumption

Vegetable	Water (%)	Energy (kcal)	Protein (g)	Fat (g)	Carbohydrate (g)	Fiber (g)	Ca (mg)	P (mg)	Fe (mg)	Na (mg)	K (mg)
Tomato	94	20.5	1.05	0.2	4.5	1.15	11.5	26	0.4	9	220.5
Onion	89.5	37	1.35	0.15	8.7	2	47	32	0.85	9.5	210
Pepper(hot/chili)	88	40	2	0.2	9.5	1.5	18	46	1.2	7	340
Pepper(sweet)	94	20	0.9	0.2	4.6	1.7	10	20	0.3	3	175
Pumpkin	92	26	1	0.1	6.5	0.5	21	44	0.8	1	340
Squash	91.3	29.2	1.2	0.2	6.9	1.4	24	33.7	0.5	4.5	287.5
Cucumber	95	15	0.7	0.1	3.6	0.5	16	24	0.3	2	147
Melon	90.7	32.7	0.8	0.1	8	0.9	8.7	10.3	0.2	14.3	225.7
Watermelon	92	30	0.6	0.2	7.6	0.4	7	10	0.2	1	112
Eggplant	92	24	1	0.2	5.7	3.4	9	25	0.2	2	230
Mushroom	92	22	3.1	0.3	3.2	1.2	3	85	0.5	4	314
Okra	90	31	2	0.1	7	3.2	81	63	0.8	8	303
Sweet corn	76	86	3.2	1.2	19	2.7	2	89	0.5	15	270

Source: Adapted from USDA *Nutrient Database*

Importance in the National Economy

Food security, income generation and employment

Warm season vegetables are among the most important sub-sectors in the national economy. They are the most popular vegetable crops with versatile food and culinary uses providing micronutrients, fiber, vitamins and minerals essential for a balanced and healthy diet. In addition to supplying energy and building our body, they have been linked to the prevention of or fight against many types of diseases including cancer. Tomato, pepper, onion and other warm season vegetables are used in every Ethiopian house as components of the daily diet. They are used as fresh vegetables and as ingredients of 'Wot', an Ethiopian stew in a daily traditional meal. Despite the importance of vegetables in daily food preparation, consumption per capita is low (Fig. 2). Seasonality of production, perishability, food habit and attack from diseases and insects are among a myriad of factors attributable to low consumption. The sub-sector is labor

intensive and plays great role towards creating job opportunities with a particular focus on engaging women, youth and poor households. Vegetable crop cultivation will facilitate additional jobs creation and women involvement in the output marketing and processing. Furthermore, the nature of the crops requires special skill and knowledge.

Warm season vegetables are major sources of cash income for smallholder as well as commercial farmers. When compared with cereals and other crops, vegetables are the most preferred crops for irrigated agriculture because of high productivity and short growing period of vegetables enabling the production of two to three season cycles per year. The return from vegetables per unit area is several folds higher than from major cereals. Market oriented productions using both irrigated and rain fed conditions have been expanding enabling various actor including growers, merchants, consumers, middlemen, transporters, to take part and benefit in the value chain of this important horticultural venture.

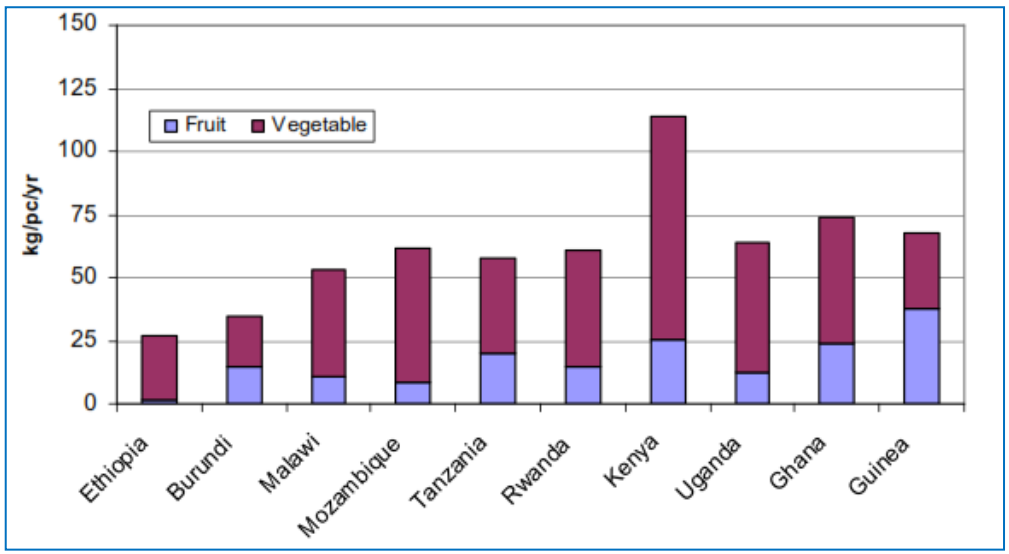

Figure 3. Fruit and vegetable per capita consumption in sub-Saharan Africa
Source: (Marie *et al*., 2004)

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Supply of raw material for local agro-industries

Warm season vegetables are used as raw materials for agro-processing industries. Processing of vegetable crops have been given high priority in the country and as a result access for both local and international markets for processed vegetable products is available (e.g. fresh chilies, frozen vegetables mixed with legume vegetables, tomato paste, tomato concentrate). Currently there are four vegetables processing plants in the country viz Melge Wondo, Gondar, Merti and Green Star food processing factories produce tomato paste and canned vegetables both for local and export markets thus creating job opportunity and generating foreign currency.

Tomatoes are processed and canned as a paste, sauce, ketchup and juice. Paprika oleoresin which is used in a wide assortment of foods, drugs and cosmetics are extracted from peppers. Capsaicin extracted from pepper is also used in the pharmaceutical industry.

Export market and foreign currency earnings

Fresh vegetables have been exported to neighboring African countries (Sudan, Somalia, Djibouti), the Middle East and the EU and generated much foreign currency. The export of fresh and processed (frozen, canned, dried and ground) vegetables has been increasing considerably. In the period between 2010 and 2014 the amount of vegetables exported increased from 51.3 thousand tones to 153.3 thousand tones while the value generated increased from 32.4 million USD to 353.6 million USD (Fig. 3). Somalia, Djibouti and Indonesia are the major importers of Ethiopian vegetables and vegetable products accounting for 68%, 15% and 7% of the export value, respectively (Fig.4). Despite the promising trend of export and the potential of the sub-sector owing to the proximity of the country to non-agricultural oil producing countries, the sub-sector has yet to improve production, productivity and quality to be able to satisfy local demand and export at competitive price with suppliers from South American countries.

Summary of export of fresh, dried and value added/processed vegetables

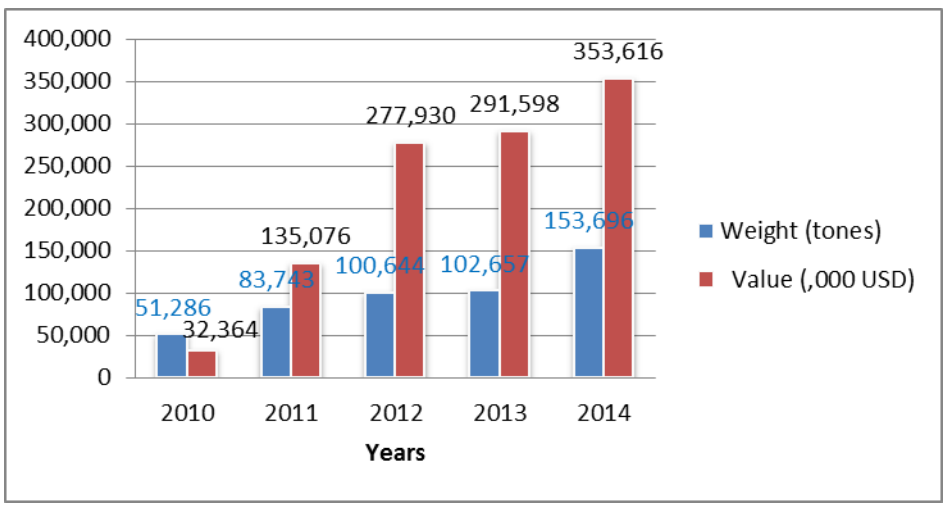
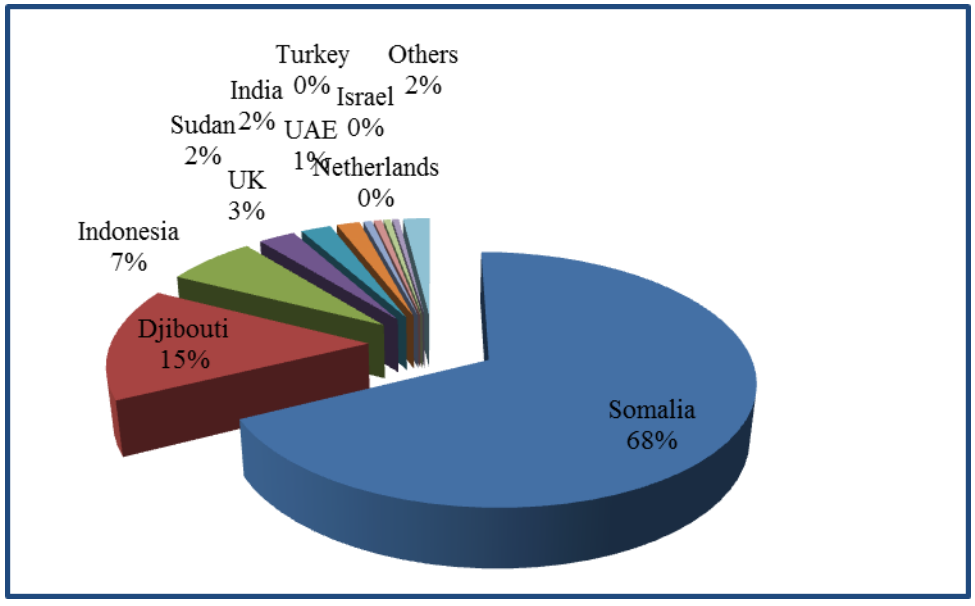


Figure 4 Summary the export value and volumes of fresh, dried and value added/processed vegetables from Ethiopia
Source: www.erca.et.com



Source: www.erca.gov.et

Figure 5. Percent of vegetable export income obtained from different countries

Environmental Sustainability

Properly scheduled and implemented vegetable production system can help to alleviate poverty, provide nutrition security, improve livelihoods, maintain ecosystem and good health, conserve biodiversity, and importantly alleviate greenhouse effects by carbon sequestration. Vegetable are produced throughout the year either rain fed or using irrigation which enable efficient use of land, rotation and increase production.

Assessment of External and Internal Environments

External Environments

The external environment of a program offers important reference points for guiding a research institute. In the external environment, the program finds its greatest reason for existing: its clients, users, beneficiaries, partners and competitors; and the forces that form social, economic, political, technological, and institutional trends. All these imply the emergence of new realities and situations that bring about new demands, challenges, risks, and uncertainties, and new opportunities and threats to the program. Therefore, changes regarding the program should start with analysis of the external environment that affects the program.

The external factors were analyzed using the SWOC (Strength, Weakness, Opportunity and Challenge) framework with additional analytic tools such as PEST+ (Politics, Economics, Socio-cultural, Technologies and Environments/situation).

Political dimension: Assessments were made whether the strategy is aligned with the national, sectoral and institutional policy, strategy and regulatory/legal frameworks and priorities. Since the adoption of the Agricultural Development Led Industrialization (ADLI) by the government, all the policy and strategy frameworks and development programs recognized agriculture to be the engine of Ethiopia's economic growth and development yet exerting relentless strive to promote steady growth of the industrial sector. The current GTP II which provides even greater emphasis to industrialization places utmost priority to those agricultural sub-sectors fostering supply of raw materials for the growing agro-industries and import substitution. Therefore, so many opportunities are set forth by the policy environment to promote research and development of the vegetable crops. As conducive the policy and legal frameworks put in place are, there are also a number of challenges that may surface in due course. Conceivable features of the opportunities to make use of and challenges to be aware of or need to be addressed, from the perspective of the policy dimension, were assessed and sorted out in a matrix of opportunities and challenges presented in Table 4 below.

Economic dimension: The increasingly rising demand of vegetable crops as a result of increasing population and changing lifestyle create the opportunity for the sub-sector to boom. Such an increase in the demand side will trigger famers to increase their outputs. The research has to, therefore, keep pace with the need of the farmers to increase production mainly through increasing productivity and minimizing postharvest losses; while meeting the demand of the industries for raw materials that are not only sufficient to enable them run in full capacity but also fulfill their requirements of quality standards. The presence of various agro-ecologies and new potential areas to grow vegetables will allow the country to be self-reliant in vegetable; and also for supplying to the potential export markets in neighboring countries and beyond. The number of commercial farms engaged in vegetable production has been increasing which play a great role for supplying high standard vegetable produce and products to regional and international export markets.

Socio-cultural dimension: It essential to clearly understand the opportunities and challenges in order to address or change the perception of the farming society that have been growing warm season vegetable crops and handled as such to be economically, socially, environmentally profitable, viable and sustainable venture. Therefore, the opportunities accruing and challenges emanating from socio-cultural settings around production, processing and trade of warm season vegetables are examined and presented as elements of the SWOC analysis.

Technological dimension: Outstandingly peculiar feature of vegetable crops is the fact that right after production the produce has to be taken to the industries for processing or to the market. Melge Wondo, Gondar, Merti and Green Star food processing factories produce tomato paste and canned vegetables both for local and export markets thus creating job opportunity and generating foreign currency. Clustering and formation of vegetable producing associations which in turn are linked with organized smallholder farmers whereby the two parties enter contractual agreements to supply to the local or exporting markets and to agro-processing industries. This is a good start that should be pursued to engrain value chain approach which in the future will play a key role for the sub-sector to gain momentum.

Environmental dimension: The presence of wide diversity of agro-ecology in Ethiopia favors to grow all kinds of vegetables including seed production. Such divers ecological factors and crop types, provides a fertile ground for a range of pathogens, insect pests, weeds especially parasitic weeds and other menaces to co-evolve with and survive on the crops, against the interest of man. The damages from these biotic factors coupled with climatic and edaphic factors hindering normal growth and development of the crops are among the primary issues that the research team would target to address.

Stakeholder analysis

A list of stakeholders with different roles and demands were examined as these stakeholders play a crucially important role for successful designing and implementation of the strategy and the outputs and impacts thereof. Therefore assessments were made what opportunities the research team could make use of and, by the same token, what challenges it should face up to coming from these stakeholders by merely being involved in providing services of agricultural extension, production, processing, trading and research.

Table 7. Stakeholders/collaborators of the research sector

No	Names of Partners	Role
1	Ministry of Agriculture & Natural Resources	Develop, coordinate and implement national horticultural development strategies and policies, packaging new technologies and dissemination
	Small holders horticulture Directorate	Coordinate implementation and regional ownership in collaboration with the hort. and irrigation offices of Regional BoAs. Take the lead role in organizing joint planning, M&E to align all stakeholders over the sector strategy.
	Small holders Irrigation Directorate	Would contribute in linking producers and consumers.
	Plant health regulatory and quarantine Directorate	Oversee vegetable varieties in use in different agro-ecologies
	Input Supply Corporation Directorate	Facilitate fertilizer and agro chemicals technologies linkage through private distributors and cooperative unions
2	Regional Bureau of Agriculture	Develop, coordinate and implement regional horticultural development strategies and policies, packaging new technologies and dissemination.
3	Higher Learning and Regional Research Institutions	Collaborate in national research and adapt/develop, release technologies/information specific to the region, multiply and demonstrate.
4	Government organizations (ATA, EHDA)	Enhance and support capacity in vegetable development program, training, advisory services Facilitate introduction of technologies to enhance production and handling of export commodities at global level
5	Ethiopian Seed Growers and Processors/ Enterprise/ input suppliers/ Private Companies and other NGO's	Strengthening seed system and facilitation of seed law policies/ demand driven input supply/ mechanization of vegetable production (technology introduction, technology transfer, knowledge and skill).
6	Small scale farmer associations, Primary cooperatives and unions	On farm technology evaluation, multiplication, adoption and dissemination, input supply and provide market information and involved in collecting and preparing vegetables for export
7	Ministry of Water Irrigation & Energy	Undertake the management of water resource Involve in the mapping & knowledge-building around water resources Enforce water use policy
		Develop & implement national standards to regulate, import materials quality

8	Ethiopian Standard Agency	Regulate the quality of fresh vegetable products with Conformity Association Enterprise of Ethiopia
9	Ministry of Trade	Develop and implement policy issues facilitating production and marketing of vegetable crops for domestic and export
10	Ministry of Industry	Facilitate expansion of agro-processing industries and strengthening linkage among different stakeholders (provide information for research for development of technologies for agro processing industries)
11	Ethiopian and Regional Seed Enterprises	Facilitate and multiply adequate quantity of improved seed for improved varieties
12	Agro-Processing Industries	Technology demand, development of value added products and provide technical support
13	National and Regional Soil Testing Laboratories	Provide advisory services and collaborate in soil related research.
14	Ethiopian Food, Beverage and Pharmaceuticals Development Institute	Provide training and advisory services, development and implementation of need based development strategies and policies and provide export market expertise.
15	Oromia Irrigation Development Agency (OIDA)	Cooperate in providing improved irrigation technology at research Centers
16	Ethiopian Biodiversity Institute (EBI)	Germplasm exchange, conservation and maintenance for research, collaborating in research
17	Quality & Standardization Authority	Information exchange
18	Ethiopian Public Health Research Institute	Joint research and information exchange
19	Central Statistic Agency Ethiopia (CSA)	Provides of official statistic information on the production and productivity of vegetable crops in the country
20	International Research Institutes (AVRDC, NRI, IPGRI, KOPIA, ACIAR, ICIPE, ASARECA, etc.)	Involve on collaborative project development and implementation, capacity building, provide germplasm and information in recent scientific advancements.

Benchmarking

As part of the external environmental factors, it is also a cogent exercise to examine the potentials of the crops which can be exploited by drawing lessons from other countries that have advanced levels of research achievements. Accordingly, comparisons, in terms of diversity of crops grown, area coverage, production and productivity were made between the status available in the national research system, countries with the highest records (China and India) and that of the world which, for the purpose of this strategy, are considered as benchmarks (see Table 4). In terms of production, Ethiopia's share of production of for major warm season vegetables such as tomato, onion and pepper is negligible and it is many folds lower than the major producers (Table 5). In terms of crop diversity grown, the major warm season crops grown in Ethiopia are only onion, tomato and pepper whereas the production of other warm season vegetable crops such as pumpkin, squash and guards, cucumber, watermelon, melon, egg plant and okra are almost negligible.

The wide productivity gap between the bench-marked nations and Ethiopia is mainly because of sufficient number of highly trained researchers at each discipline, and higher level of technological advances in facilities, acquisition and maintenance of diverse gene pool, use of biotechnological tools geared toward generation of hybrid varieties, protected horticulture (advanced climate control and

fertigation systems). Therefore, step by step building of capacity of researchers and facilities is unequivocal to narrow the productivity gap.

Table 8. Comparison of area, production and productivity of major vegetables of Ethiopia with major producers and the world average

Crop	Country	Area (ha)	Area ratio	Production (ton)	Production ratio	Productivity (t/ha)	Productivity ratio
Onion	Ethiopia	21,865		219189		10.5	
	China	1025000	46.9	2600000	11.9	22.0	2.1
	India	1051527	48.1	16813010	76.7	16.0	1.5
	USA	60000	2.7	3277460	15.0	54.6	5.2
	Kenya	7751	0.4	112243.6	0.5	11.2	1.1
	World	4296495	196.5	83355752	380.3	19.4	1.9
Tomato	Ethiopia	7,237		55514		9.6	
	China	1000000	138.2	50000000	900.7	50.0	5.2

	India	879632	121.5	18226635	328.3	20.7	2.2
	USA	150140	20.7	13206950	237.9	88.0	9.2
	Kenya	24554	3.4	503172	9.1	20.5	2.1
	World	4813312	665.1	162520469	2927.6	33.8	3.5
Pepper (dry)	Ethiopia	136,504		316561		2.3	
	China	44000	0.3	300000	0.9	6.8	2.9
	India	792000	5.8	13760000	43.5	1.7	0.3
	Kenya	2500	0.0	3000	0.0	1.2	0.5
	World	197910	1.4	3458634	10.9	1.8	1.0

(Source: CSA, 2014; FAOSTAT, 2014)

Assessment of Internal Environments

Assessment of strengths and weakness of the program in terms of capacities that exist within the EIAR system such as resources (human, physical and financial resources); technical or technological and organizational capacity, functional integrations within and between disciplines were thoroughly examined. Inter- and intra- disciplinary integrations, complementarities and synergies were also assessed. Furthermore, technologies available for warm season vegetable since the start of research in the country and required with regard to the current and future demand of the farming communities were analyzed (Table6)

Strengths, Weaknesses, Opportunities and Challenges by the Research Themes

Table 9. Internal and external situations analyses on warm season vegetables research

Thematic area	Internal Environment/situation		External Environment/situation	
	Strength	Weakness	Opportunities	Challenges
Breeding and Genetics	• Agro ecologies based research centers; • Established research system (modest research experience and resources); • Availability of varieties of tomato, onion and hot pepper.	• Insufficient and lack of systematic genetic resource collection, introduction and management system; • Limited varieties (ops and hybrids) with high yield and desirable quality; • Lack of varieties for international export market and agro-processing industries; • Limited varieties adapted to different production season, agro-ecologies and production system (protected cultivation, organic production and home garden); • Limited breeding for stress resistance againast major pest and diseases and prevailing enviromental stresses (heat, salinity, drought); • Lack of strategic breeding for development of functional and nutraceutical products; • Inadequate facility and frequent training for researchers and technicians on modern breeding tools • Limited institutional and resource capacity as a result of insufficient national priority given to vegetable research;	• Favorable agro-ecology, potential irrigation water, expansion of micro irrigation schemes, identified growth corridors; • Availability of genetic diversity, though narrow, for some of vegetable crops such as okra pumpkin and chilli; • Presence of policies and regulations on germplasm exchange and introduction and plant quarantine; • Availability of export oriented commercial vegetable farms and collaborating institutions (EHDA, EHPEA, ; • Availability of modern biotechnological tools and facilities elsewhere to adopt, adapt and use; • High demand of varieties especially for export market and agro-processing industries; • Involvement of International and local private companies on introduction, adaptation and	• Limited access to broad germplasm; • Climate change , quarantine pests and diseases and prevailing environmental stresses (heat, salinity, drought); • Lack of seed system and organizations involved in multiplication of adequate and quality seed; • High turnover of skilled research staff and • Poor linkage of the research with other stakeholders along the value chain.

		• Limited capacity of using modern biotechnological tools (MAS and DH techniques);. • Lack of capacity in bioinformatics, genotyping, sequencing and their utilization in molecular breeding and • Shortage of breeder pre-basic seeds in sufficient quantity and quality.	registration of varieties and • Availability of decentralized research on regional, federal and higher learning institutes.	
Crop protection	• Pest management practices are available for several major pests of vegetable crops; • Continuous registration of new agrochemicals; • Acceptable achievements in generating arthropod pest management technologies and information and • strong contribution to national and international scientific communities through publication , documentation and distribution of outcomes of agricultural entomology researches.	• Limited information on biology and ecology of pests; • Insufficient IPM packages and pesticide based pest management; • Limited or absence of basic research on major arthropod pests and • Recommended arthropod pest management methods so far were not IPM oriented.	• Possibility of acquiring IPM options from different research institutes and countries; • Encouraging policy and public and private investment on protection; • High demand for arthropod management technologies by different clients and • availability of web based arthropod pest information.	• IPR issues and absence of policy for the regulation of bio-control options; • Frequent pest outbreaks due to changing environment and tropical nature of the country; • Ineffective quarantine/ regulatory system and surveillance; • Accidental introduction of new invasive arthropod pests to the country and • Absence of entomology extension and advisory system.
Agronomy and Physiology, Nutrient and Irrigation water management	• Availability of blednded fertilizers and construction of fertilizer factories • Increasing focus on warm season vegetables	• Limited and blanket recommendations for different production season, agro-ecologies, production system and crop types • Lack of standardized modern seedling propagation techniques; • Lack efficient water management techniques; • Limited integrated nutrient management	• Availability of precision agriculture technologies (remote sensing) elsewhere to adopt, adapt and use; • Government policy and focus on full package for increased productivity and production to realize food security; • Availability of physiological	• Reliance on chemical fertilizers • Climate change causing recurrent drought and famine limiting farmers capacity to utilize full packages; • Lack of equipments in physiological research and • Less focus on human power development programs in the

		system; • Limited information on vegetable cropping system; • Lack of agronomic recommendations for emerging protected , organic, and home garden vegetable production system; • Limited focus on physiological research; • Limited utilization of crop modeling tools and • Less focus on clustering of environments against disease pressure, high yield and quality.	facilities elsewhere for application to incorporate physiological traits and • Wide availability and applicability of crop modeling tools to predict future crop production senarios.	area of crop physiology.
Quality and Postharvest Management	• Central and satellite labs for quality and nutritional analysis set by EIAR; • Some post-harvest handling (PPH) and semi- processed value added technologies and experiances are available.	• Absence of vegetable based value added food products; • Lack of small scale preservation and processing technologies; • Limited awareness on importance of vegetables in terms of nutrition and consumption; • Lack of strategic research on development of functional and nutraceutical products from vegetable crops and • Absence of effective and simple packaging technologies.	• Favorable policy incentives for agro-processing industries for export market; • Common certification setting(EHPEA); • Increased local demand for processed vegetable products; • Possibility of acquiring technologies related to postharvest management and value addition and	• High investment cost of post-harvest technologies • Absence of local-GAP, strict global food safety standards and costly certification process • Unfavorable legislations on import substitution • Lack of investment in sector-specific infrastructures and logistics
Agricultural Mechanization		• Lack of small-scale farm implements (planters, transplanter, threshers, seed extractor, land leveler, harvester, magnetic sprayer, mechanical weeder); • Inefficient water lifting devices (standardized pumps), transport mechanisms, naturally ventilated short	• Emerging engineering industries to modernize vegetable industry through developing equipment for PPH(post harvest handling) managements, packing and processing.	• Advanced and expensive agricultural equipment in vegetable value chain makes the technologies unaffordable by smallhoder growers

		term storage structures.		
GIS and agro-meteorology	• GIS and agro meteorology research units are established in most research centers	• Lack of GIS based suitability map for major vegetable crop production	• Sophisticated GIS and agro-meteorology Technologies available worldwide	• Big technological and research capacity gap and the technologies are expensive
Technology multiplication		• No involvement in vegetable seed multiplication • Lack of seed multipler within EIAR except the program	• Strong demand from stakeholders for improved seed	• Lack of seed system and absence of responsible vegetable seed multiplying enterprises • Limited facility and expertise in vegetable seed quality research
Agricultural Economics, extension and gender		• Weak delivery of existing technologies to producers; • Poor linkage among stakeholders especially the private sector; • Limited information on vegetable technology adoption and impact; • Limited awareness of vegetable production technologies, consumption post harvest and utilization	• High demand for vegetables products • Existence of vast extension system (GOV & NGOs') and supportive technology promotion policy, marketing systems, etc. to adopt • Expansion and improvement of communication, physical infrastructures	• Weak linkage among extension actors

Capacity Building		• Lack of planned and specialized training (short and long); • Limited research facilities (laboratories and equipments for advanced physiological, molecular pathological data collection and seed test, efficient irrigation system, cold stores, post harvest storage facilities, seed laboratories, green houses, lath houses, offices, machineries, vehicles) ; • Shortage of field and laboratory supplies; • Inadequate budgeting for research operations and capacity building; • Inefficient procurement process and • Limited organizational structure of the program.	• Availability of graduate horticulturist on the market	• Continuous turnover of experienced research staff • Inefficient procurement system for utilizing the available resources • Inadequate budget for procurement of required facilities

Strategic Issues Facing the Warm Season Vegetables Research

The key strategic issues for intervention were categorized in to technological packages, capacity building and organizational structure of warm season vegetable research program.

Technological Packages: Since the start of vegetable research in the country, efforts have been made to improve vegetable production with improved technologies (varieties, crop management practices, pest control recommendations and post harvest technologies). However, there are still gaps, in the major strategic issues identified to be intervened in the following thematic areas: 1) Genetics and breeding; 2) Agronomy, physiology and nutrient management 3).Irrigation water management; 4) Crop protection; 5) Technology multiplication 6) Agricultural mechanization; 7) Food science, postharvest technology and nutrition; 8) GIS and agro-meteorology; and 9) Agricultural economics, extension and gender. The strategic issues are presented under each thematic area.

Research Capacity: Almost all research centers including the co-coordinating center Melkassa Agricultural Research Center (MARC) have limited research facilities, infrastructure and qualified and senior research staff.

Organizational Structure: Vegetable crops research is recently reorganized from a single commodity into two separate programs; and yet several vegetable crops are considered in a research program. Warm season vegetable research program, for instance, addresses capsicum *spp*, tomato, onion, snap bean, okra, egg plant, amaranths, cucurbits etc. Further restructuring the research programs into groups of specific crops will help to focus on delivering appropriate technologies.

Table 10.List of thematic areas and strategic issues

Thematic areas	Strategic issues
Genetics and breeding	• Limited and lack of access to broad genetic resources
	• Improved varieties (OP and hybrid) with high quality, yield and resistant to biotic and abiotic stresses for diverse agro-ecologies and uses (nutrition, processing, export market, protected cultivation and organic culture)
	• Basic research knowledge and skill
	• Application of biotechnology
	• Maintenance breeding and breeder seed
Agronomy , Physiology and nutrient management	• Seedling propagation techniques and nursery management
	• Agronomic practices, integrated nutrient management and cropping system
	• Production systems (organic, protected and home garden production)
	• Physiology
Irrigation water management	• Irrigation agronomy (efficient water management)
Crop protection	• Basic information on major vegetable pests
	• IPM packages
	• Pesticide residues
	• Pesticide resistance
Technology multiplication	• Adequate and quality seed production
	• Seed system
Agricultural Mechanization	• Small-scale farm implements
	• Pump, transportation mechanisms, storage structures
Food science, postharvest technology and nutrition	• Value added food products
	• Nutritional characteristics and quality related traits
	• Postharvest management
	• Packaging technologies
climate smart agriculture (CSA)	• GIS for operation of farm practices
	• Vegetable production suitability map
Agricultural economics, extension and	• Technology promotion

gender	• Linkage among stakeholders especially the private sector
	• Inclusiveness (gender, youth & disabled)
	• Farming systems
	• Adoption and Impact
	• Marketing and Policy
Capacity Building	• Physical
	• Human
	• Finance

Research Themes and Strategic Interventions

The research strategic interventions are outlined below in short (2016-2020), medium (2021-2025) and long-term (2026-2030) interventions, and under each of these by the identified thematic areas of intervention.

Table 11. Strategic interventions planned to address critical issues facing the warm season vegetables research commodities in the short-, medium- and long- terms

Strategic issues	Strategic Intervention		
	Short-term (2016-2020)	Medium-term (2021-2025)	Long-term (2026-2030)
1. Genetics and Breeding			
Capsicum wilt	• Introduction of wilt resistant lines • Collection and characterization • Parental selection and evaluation	• Understand the inheritance mechanism • Crossing block establishment • Grafting between selected lines	• Hybrid development
Access to broad genetic resources	• Strengthen collaboration with international institution (AVRDC, IPGRI) for germplasm source; • Systematic genetic resource collection, introduction and management of desirable traits (stress tolerant, yield and quality); • Initiate crossing and generate genotypes from segregating population.	• Continue enriching germplasm base through collection and introduction with desirable traits • Strengthening crossing and generate genotypes from segregating population	• Continue introduction, collection and collaboration with international institutions for sources of germplasms; • Strength crossing block and generate genotypes from segregating population;
Improved varieties (OP and hybrid) with high quality, yield and resistant to biotic and abiotic stresses for diverse agro-ecologies and uses	• Introduction, adaptation and registration of commercial varieties with high yield and desirable quality and uses (processing, export market); • Development of varieties for high yield and quality and • Development of varieties for export market and processing industries.	• Introduction, adaptation and registration of commercial varieties with high yield and desirable quality and uses (processing, export market); • Development of improved varieties with high production potential, biotic and a biotic stress tolerance; • Development of varieties for various uses (export market, processing, protected and organic culture) and • Development of parental lines for hybrid development for tomato and capsicum.	• Introduction, adaptation and registration of commercial varieties with high yield and desirable quality and uses (processing, export market); • Develop varieties for different production system (protected, organic, rain fed and irrigation); • Development of hybrid tomato and capsicum varieties for yield and quality and • Development of improved varieties with high production potential and resistance to major disease and other stresses (salinity and heat).
Basic research knowledge and skill	• Generate basic scientific information regarding stress resistant, inheritance and	• Generate basic scientific information regarding stress resistant, inheritance and	• Generate basic scientific information regarding stress resistant,

	gene action • Generate information on nutritional quality of warm season vegetable varieties and selected germplasms	gene action	inheritance and gene action
Application of Biotechnology	• Molecular characterization of varieties and /or germplasm of tomato, capsicums, okra	• Continue to characterize available germplasms of tomato, capsicums, okra using molecular tools with desirable traits such as disease , heat, drought resistance; • Initiate and employ MAS in capsicum and tomato breeding and • Initiate and employ of DH line development and evaluation for desirable traits for capsicum.	• Continue to characterize available germplasms of tomato, capsicums, okra using molecular tools; • Strengthening of MAS in capsicum and tomato breeding and • Strengthening of DH development and evaluation for desirable traits in capsicum.
Maintenance breeding and breeder seed	• Maintain and produce breeder seed of released warm season vegetable varieties with sufficient quantity and quality	• Continue to maintain and produce breeder seed of released warm season vegetable varieties with sufficient quantity and quality	• Continue to maintain and produce breeder seed of released warm season vegetable varieties with sufficient quantity and quality
2. Agronomy, Physiology and Nutrient Management			
Seedling propagation techniques and nursery management	• Develop nursery management technologies • Plant protection in vegetable nursery	• Adoption of nursery media technologies • Development of nursery media from local materials	• Water management and hardening of seedlings at nursery • Plant nutrition and its management in vegetable nursery
Physiology	• Determine seed germination rate, dormancy period and priming techniques and development); • Determine response of different vegetable crop varieties under greenhouse.	• Conduct crop physiological studies (water use efficiency, photosynthetic efficeincy, nutrient use efficiency,crop growth and development)	• Continue crop physiological studies (water use efficiency, photosynthetic efficeincy, nutrient use efficiency,crop growth and development)
Agronomic practices, integrated nutrient management and cropping system	• Refine and update production technologies (fertilizer rate, spacing) for tomato, capsicum and onion; • Generation of cropping systems for	• Develop vegetable based cropping system (crop rotation, intercropping pattern); • Continue determination of optimum nutrient application for different vegetable	• Determine optimum micro nutrient rate and frequency of application in tomato, onion and capsicum • Continue generation of cropping

	different climatic conditions (crop rotation, intercropping); • Optimize organic and inorganic fertilizer combination ratio for major vegetable crops and • Determination of optimum nutrient application for different vegetable and agro-ecologies.	and agro-ecologies and • Determine soil test-based crop response information.	systems for different agro- climatic conditions (crop rotation, intercropping)
Production systems (organic, protected and home garden production)	• Identification and adoption of home garden culture for urban and pre urban agriculture.	• Development of crop management practices for organic production (biofertilizer, biopesticide, plant density, mulch); • Development of crop management practices for protected culture and • Development of crop management practices for home garden production (media, density).	• Development of vegetable home garden production model for urban and pre-urban corridors • Development of technologies for protected cultivation (tomato, cucumber, capsicum (spacing, fertigation and irrigation)
3. Irrigation water management			
Irrigation agronomy (efficient water management)	• Determine crop water requirement coefficent and irrigation amount and frequency	• Development of efficient water management (micro-irrigation and fertigation and irrigation scheduling) available for major vegetables	• Continue development of efficient water management (micro-irrigation and fertigation and irrigation scheduling) available for major vegetables
4. Crop protection			
Basic information on major vegetable pests	• Exploratory insect, disease and weed pests surveys • Determine seasonal abundance of major pests and associated regulatory factors	• Assess crop losses due to major pests; • Studies on mechanism and breeding for resistance and • Develop pest forecasting system.	• Generate information on outbreak, biology and ecology of pests of vegetable crops; • Study of biology of major pests under laboratory condition; • Epidemiology and population dynamics studies of major pests

IPM packages	• Integration of identified cultural control methods with other tactics • Trap networking for major disease and insect pests	• Assess the efficacy of cultural, mechanical and physical control methods on controlling major pests; • Introduce and evaluate exotic natural enemies against major pest problems and • Determine indigenous natural enemy complex associated with major pests.	• Assess the efficacy of microbial products for the control of major pests; • Studying genetics of resistance and incorporating host plant resistance to IPM; • Identification of source of resistance against major pests; • Release and assess the establishment and effectiveness of natural enemies in bio-control method.
Pesticide residues	• Awareness creating through training	• Continue awareness creating through training	• Continue awareness creating through training
Pesticide resistance	• Determine occurrence of pesticide resistant biotypes of major pests; • Conduct studies on reduced rate and critical time of application; • Resistance management studies and • Training on and demonstration of rational use of pesticides	• Continue determining occurrence of pesticide resistant biotypes of major pests; • Evaluation of new and IPM compatible pesticides; • Strengthen Resistance management studies and • Continue training on and demonstration of rational use of pesticides.	• Continue determining occurrence of pesticide resistant biotypes of major pests; • Evaluation of new and IPM compatible pesticides; • Strengthen Resistance management studies and • Continue training on and demonstration of rational use of pesticides.
5. Technology multiplication			
Adequate and quality seed production	• Basic and pre-basic seed production of improved varieties of vegetables and • Development of harvest and post-harvest seed management techniques.	• Continue basic and pre-basic seed production of improved varieties of vegetables • Continue development of harvest and post harvest seed management techniques	• Continue development of harvest and post-harvest seed management techniques; • Production and supply of early generation continue;

Seed system	• Establishment of innovative platform for production and marketing vegetable seed production • Providing technical support for community based seed producers for quality and sustainable seed production	• Continue establishment of innovative platform for production and marketing vegetable seed production • Continue providing technical support for community based seed producers for quality and sustainable seed production	• Continue establishment of innovative platform for production and marketing vegetable seed production and • Continue providing technical support for community based seed producers for quality and sustainable seed production
6. Agricultural Mechanization			
Small-scale farm implements	• Development of manual and engine operated tomato seed extractor • Undertake inventory of locally existing technologies	• Conduct evaluation, verification of local existing technologies and demonstration • Development of vegetable seed planters, seed threshers	• Development of magnetic pesticide sprayers.
Pump, transportation mechanisms, storage structures		• Develop appropriate improved storage facilities through adoption, introduction and reverse engineering and copying from public domain	• Continue to develop appropriate improved storage facilities through adoption, introduction and reverse engineering and copying from public domain
7. Quality and Postharvest Management			
Quality and Postharvest management	• Study nutritional characteristics and quality related traits of vegetables; • Determine post-harvest losses of major vegetables; • Introduce post-harvest management technologies of vegetables for fresh market and processing; • Development of packaging technologies for different vegetables and • Develop value added products.	• Study nutritional characteristics and quality related traits of vegetables; • Determination of quality standards for industrial and export market; • Development of processing and preservation techniques; • Develop post-harvest management technologies of vegetables for fresh market and processing; • Development of packaging technologies for different vegetables and • Continue develop value added products.	• Development of functional and nutraceutical vegetable based food products; • Nutritional characteristics and quality of related traits vegetables; • Promote post-harvest management technologies of vegetables for fresh market and processing; • Development of packaging technologies for different vegetables and • Continue develop value added products.

8. GIS and agro-meteorology			
Vegetable production suitability map	• Expanding vegetable crops -climate suitability/stress mapping for the representativeness of the existing testing sites and annex new/potential sentinel sites for vegetable crops research program		• Strengthen integrated soil—vegetable crops--climate continuum (SPAC) modeling for rain-fed and irrigated system to optimize the balance between the multi-location experimentation and the computer based modeling research
GIS for operation of farm practices	• Understanding local climate and farming system dimensions (physical climate, social, economic. farming system etc) for targeting the right vegetable crops technology to the right environment	• Evaluation of the potential impacts of vegetable G*E*M combination under various vegetable growing belts towards reducing the wider yield gaps (farmers/actual yield, experimental or attainable yield and the potential yield/biological maximum); • Optimizing response to the prevailing and the resurgence of diseases and insect pests in vegetable production under the climate changed future Ethiopia.	• Optimize vegetable breeding for the shift/change in temperature (beyond the maxima) and decline in water demand under the highly likely climate changed future dates in Ethiopia
9. Agricultural economics, extension and gender			
Technology promotion	• Demonstration and popularization of major vegetable technologies; • Develop and distribute various communication material and • Organize trainings, field days and travelling workshops involving stakeholders.	• Continue demonstration and popularization of major vegetable technologies to new areas; • Coninue develop and distribute various communication material and • Continue organize trainings, field days and travelling workshops involving stakeholders	• Continue demonstration and popularization of major vegetable technologies; • Coninue develop and distribute various communication material Continue organize trainings, field days and travelling. workshops involving stakeholders
Linkage among stakeholders especially the private sector	• Establish and effectively use innovation platforms for development and dissemination of vegetables	• Strengthen and promote innovation platforms for development and dissemination of vegetables technologies	• Strengthen and promote innovation platforms for development and dissemination of vegetables

	technologies		technologies
Inclusiveness (gender, youth & disabled)	• Develop working modality to strengthen the participation of women and youth in vegetable research and promotion • Promote gender main streaming in vegetable research	• Continue strengthening participation of women and youth in vegetable research and promotion • Continue promotion of gender main streaming in vegetable research	• Continue strengthening participation of women and youth in vegetable research and promotion • Continue promotion of gender main streaming in vegetable research
Farming systems	• Survey, diagnose and document the social, economic and cultural values of vegetable production and its constraints	• Survey, diagnose and document the social, economic and cultural values of vegetable production and its constraints	• Survey, diagnose and document the social, economic and cultural values of vegetable production and its constraints
Adoption and Impact	• Determine the extent of adoption of vegetable technologies and their impact	• Determine the extent of adoption of vegetable technologies and their impact	• Determine the extent of adoption of vegetable technologies and their impact
Marketing and Policy	• Conduct value chain study and identify constraints at different stages of the value chain • Generate cost of production for major vegetable crops	• Conduct value chain study and identify constraints at different stages of the value chain	• Conduct value chain study and identify constraints at different stages of the value chain • Cost of production for major vegetable crops estimation
10. Capacity Building			
Physical	• Establishment of facilities and infrastructures ((laboratories, office, greenhouse, lath house, drip irrigation, vehicles, cold stores, storage facilities, office and laboratory equipments)	• Establishment of standard greenhouse and screen houses • Construct office and laboratory building and acquire the necessary facilities	• Upgrade lab and office facilities

Human Resource	• Recruit qualified researchers for all disciplines; • Strengthen capacity and familiarize researchers with modern scientific tools through long and short term trainings and periodical mentorship; • Organize short term and on-job trainings for support staff and • Organize experience sharing and exchange visits.	• Maintain adequate level of qualified research staff ; • Strengthen capacity and familiarize researchers with modern scientific tools through long and short term trainings and periodical mentorship; • Organize short term and on-job trainings for support staff and • Organize experience sharing and exchange visits.	• Maintain adequate level of qualified research staff; • Strengthen capacity and familiarize researchers with modern scientific tools through long and short term trainings and periodical mentorship; • Organize short term and on-job trainings for support staff and • Organize experience sharing and exchange visits.
Finance	• Allocate adequate budget, • improve the procurement process and release budget timely	• Allocate adequate budget • improve the procurement process and release budget timely	• Allocate adequate budget, improve the procurement process and release budget timely

The Next Steps

Following the approval of the strategy document by the top management of EIAR, it is essential to prepare the implementation plan, without which this strategy is not going to reach fruition. The implementation plan document will come out as Volume II of the research strategy, which will serve as the blueprint to guide the National Warm Season Vegetable Research Commodity for the next fifteen years (2016-2030). The major contents of the implementation plan will revolve, among others, around the following topics:

- Develop implementation plan;
- Develop monitoring and evaluation plan;
- Develop impact assessment plan and
- Develop reassessment plan for the strategy.

In order to expedite the development of the implementation plan, it will be important to develop a common guideline that will serve the EIAR Planning, Monitoring and Evaluation Directorate to provide guidance to the research teams develop implementation plans. This guideline is useful to communicate the goals of the strategic plans and establish uniform approaches. The guideline will contain important considerations in planning a project(s) from the developed strategic plan, including building research teams of various roles and levels. It will generally be of importance that researchers, planners and evaluators will need to become familiar with the guideline to prepare successful projects from the strategic plans as well as provide realistic estimates of resource requirements for implementing the strategic interventions projected for the short-, medium- and long-term timeframes. The guideline will, therefore, be prepared with the intention of providing a common structural and conceptual framework that can be followed by the respective teams of research commodities for preparing the implementation plans of their respective strategies.

Enset Research Strategy

Introduction

In Ethiopia, agriculture is one of the sectors considered the most critical economic pillar and contributing over 41% of the regional GDPs and directly employing over 75% of the population. As a result, Agriculture contributes the highest share of the Gross Domestic Product and foreign currency earnings of the country from the sale of agricultural outputs abroad. Moreover, the sector creates employment opportunity to the majority of the country's population and at present 83 percent of the country's population depends on agriculture to sustain their livelihood. Hence, as it had been for centuries in the past, still being the leading sector at present, it is believed to remain being the determinant sector to play a dominant role to bring about an overall sustainable economic growth to the country, for the years to come.

Agriculture is characterized by subsistence mode of production with extremely low incomes and hand-to-mouth livelihoods of the smallholder growers. As a result the current agricultural development plan developed a strategy i.e. Agricultural Development-Led Industrialization (ADLI), focuses on the commercialization of smallholder agriculture through the production of those commodities that are competitive both at local and foreign markets. This will be materialize if and only if persistent efforts to increase productivity through increase use of farm inputs such as improved seed, fertilizers and modernize the farm activity through increase use of modern and improved farm implements and farming systems as well as through the introduction of modern farming technology to the sector as a whole will be implement by the government and the concerned stakeholders including the farmer.

Enset is grown in south-western part of the country and covers considerable land area within the private holdings (Figure 1). A total of 312,171.98 hectares of land was under enset in the country, taking up about 2.30% land area covered by all crops at country level. The number of enset trees to be harvested, in the current agricultural year, from all over the country is estimated to be 112,522,152. Thus, the total produce in the form of *amicho, kocho,* and *bulla* is 23,821,849.47 quintals, 28,329,103.94 quintals and 950,414.35 quintals respectively (Table 1). In this case, enset has a strategic importance in the agricultural sector based on its contribution to food security and import substitute.

Around late 1960s enset research was started in Debre Zeit Research Center where some varietal evaluation for yield and bacterial wilt were conducted. Since 1980 enset research activities at this Center was also discontinued. In 1972/73 enset clones were collected from different enset growing areas and established at Holetta Research Center. In 1976 this collection was taken to Wolaita Agricultural Development Unit (WADU). In WADU variety and agronomic trials were conducted, but in early 1980s enset research in WADU was discontinued. Development of enset processing devices was started at Nazreth Research Center in 1977. Some processing devices were developed and introduced to users. After elapse of sometime the activity is reinitiated recently.

In 1986 Areka Research Center has been established mainly for enset research and since then improvement and agronomy trials have been carried on. At the same time, trials have been started at Hawasa Research Center on enset pathology and entomology. Currently some enset research activities are being carried by some of the higher learning institutions. Currently, enset research programs are coordinated across federal and regional research centers by Areka Agricultural Research Center. Over the years, sensible achievements have been made with respect to the development of improved technologies involving varieties along with improved management practices, generation of information and promotion of improved technologies. These achievements had been well documented and major gaps were identified through two consecutive international enset workshops carried out in 1997.

The first comprehensive national enset research strategy was developed in 2000. However, it was not implemented as planned due mainly to structural changes in the research system. The Program has been tasked to develop an integrated and multi-disciplinary national enset research strategy plan for the next 15 years. This strategy aims to sustainably develop enset technologies by different disciplines to increase the productivity of women, men and youth smallholder enset farmers to improve their livelihood and incomes, while meeting overall goals of the Ethiopian Growth Transformation Plan (GTP II).

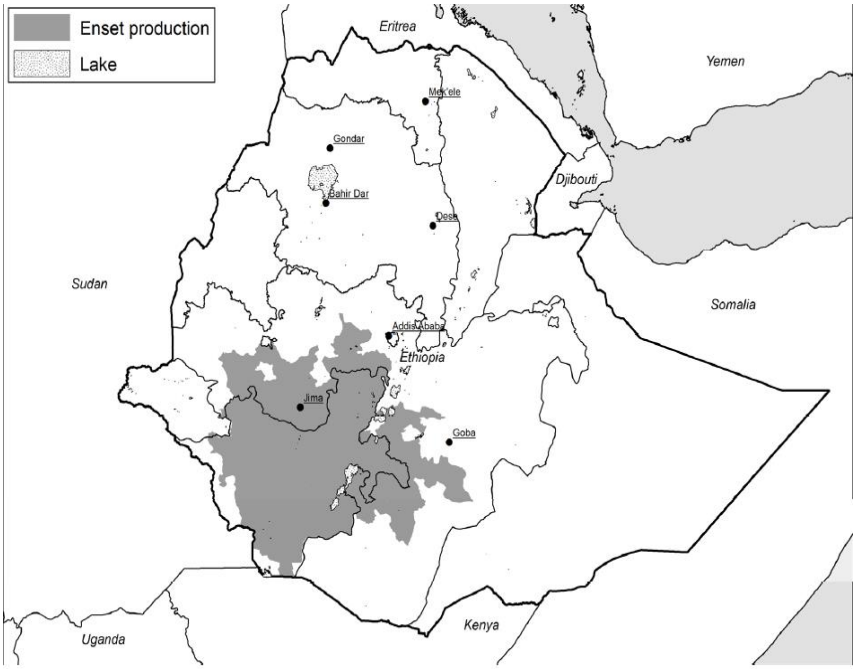


Figure 1.Geographical distribution of enset production in Ethiopia

Rationale for the Strategy

Ethiopia enters GTP-II, agricultural research in Ethiopia is found at the crossroads where urgent and quick action is needed to decide on an appropriate, effective, and sustainable national agricultural research system that would simultaneously be able to address the objective of poverty alleviation and food security on the one hand and increased competitiveness and profitability on the other.

Research in agriculture is an important, even core, element in the alleviation of poverty. Research leads towards higher levels of productivity and increasing incomes for both rural and growing urban populations. These improvements can lead to better health through better nutrition and improved local economies and services.

Therefore, investments in the rural sector must generate new knowledge through research and provide the enabling environment and market opportunities that allow research results to carry through to sustainable development outcomes.

Ethiopia need to develop the sector and increase the production and productivity; develop a national research strategy that needs to contribute to development, translating research results into development outcomes and need to be economic driver to reduce poverty and ensure food security. The lesson learned from this is that availability of production inputs, proper dissemination of proven technologies and full participation of stakeholders in the transfer process can bring significant success in enset production and productivity.

EARI rationale for developing a national enset research strategy is the belief that the crop will contribute to the food security and the economic development of enset producers and processors and the well-being of numerous disadvantaged communities and individuals in the country. All in the research program transforming itself to explore alternative options for effective coordination, resourcing, development and over-sight for the National Agricultural Research System (NARS). The strategy document will be used as a guideline and road map to direct research undertakings in developing reliable technologies that will increase enset production and productivity. This will help then contribute to achieve Ethiopia's long term vision of becoming a middle income economy.

Vision

To be a leading enset research commodity providing enset technologies, knowledge and information that enables the crop to leading food and export crop of the country.

Mission

To generate, develop and promote improved enset technologies for increasing enset productivity, policy for improving productivity, sustainable development and conserving the natural resources

Goal

The goal of enset research commodity is to enhance food security and income of enset farming communities by increasing the production and productivity of enset through efficient development of improved and sustainable technologies.

Objective

- To enhance agro-ecologically based enset production and productivity to maximize its contribution to food security and
- To strengthen market oriented/demand driven enset production and utilization through appropriate technologies that enhance income generation.

Importance of the Commodity

Agriculture

Agriculture is a major contributor to the national economy of Ethiopia, representing 41% of Ethiopia's GDP I. Enset-based farming system is one of a major agricultural system in Ethiopia that serves as a backbone for at least one-fifth of country's population. The significant feature of the enset subsector in Ethiopia has been briefly outlined as follows.

Agro-ecology and farming system

The enset agro-ecology ranges from 1200-3100 masl, but scattered plants can also be found at lower altitudes. However, it grows luxuriously in elevation between 2000 and 2750 masl. Enset is not tolerant to freezing and frost damage on upper leaves is commonly observed 2800 ma.sl and serious stunting is seen above 3000 ma.sl. Average rainfall of 1100-1500 mm per year and mean temperature of 16–20 ^{0}C is optimum for its growth. Enset grows well in most soil types provided they are sufficiently fertile and well drained. Generally, Enset is grown in more than seven out of 18 major agro-ecological zones (AEZs) in the country. Except the difference in area coverage in the respective agro-ecologies, enset is equally important in all the seven agro-ecological zones. The seven enset producing AEZs are:

Hot to warm sub-humid lowlands (SH 1)

SH1: Characterized by hot to warm lowlands and divided into 4 sub-zones. It covers 7.45% of the country. Areka and Woerabe research centers represent this AEZ.

Tepid to cool sub-humid mid highlands (SH 2)

SH2: Characterized by tepid to cool sub-humid mid highlands and It covers 7.6% of the country. Characterize this zone, and it is sub-divided into four sub-zones. Areka, Awassa Arbaminch and Jimma research centers represent this AEZ.

Cold to very cold sub-humid sub afro-alpine to Afro-alpine (SH3)

SH3: Characterized by cold to very cold sub-humid sub-afro-alpine to afro-alpine mountains. It covers about 0.47% of the country with one sub-zone of the country. It is served by Kulumsa and Sinana Research Centers.

Hot to warm humid lowlands (H1)

H1: Characterized by hot to warm humid lowlands and consists of three sub-zones. This zone is partly represented by Jimma Research Center

Tepid to cool humid high lands (H2)

H2: Characterized by tepid to cool humid mid highlands and consists of three sub-zones. The area includes southern part of Oromia and SNNPR. Different root and tuber crops and vegetable crops are successfully produced. It is represented by Bonga, Jima and Tepi research centers.

Tepid to cool moist mid highland (M2)

M2: Characterized by tepid to cool moist mid highlands and sub divided into five sub-zones. Ambo, Holetta, Kulumsa and Yabelo research centers represent this AEZ.

Cold to very cold sub-afro-alpine to Afro-alpine (M3)

M3: cold to very cold moist sub-afro-alpine to afro-alpine: It covers 0.64% of the country with one sub-zone. Ambo and Holetta research centers represent this AEZ.

Genetic Diversity

Basic botanical differences established between the two genera i.e. *Musa* and *Ensete* of the musaceae family. Ethiopia is one of the primary centers of origin and diversity for enset. Hence, the country harbors huge wealth of genetic diversity in the enset crop. Farmers' rich knowledge that is accumulated on the crop over many years has played a significant role in naming, characterization and maintenance of the existing genetic diversity. Enset producing farmers have their own folk naming and classification system to distinguish one landrace from the other. Sometimes it is difficult to understand and reclassify, even while watching them to characterize. The classification of enset landraces has been accommodated by phenotypic differences, unique traits and specific uses of landraces. These are common characteristics of folk classification systems in enset. Folk nomenclature is an integral part of the variety management in enset farming systems. In general, this study and the previous studies have shown that different ethnic groups in the enset farming system demonstrated the existence of considerable amount of indigenous ethno-botany knowledge. High landrace diversity in a region may indicate extended periods of enset cultivation and a more subsistence form of production.

Production and productivity

Enset-based farming system is one of a major agricultural system in Ethiopia that serves as a backbone for at least one-fifth of country's population. Enset has been selected as a

typical multipurpose crop of which every part is thoroughly used for food, feed, medicinal, construction and ornamental purposes. Throughout the growth stage the corm, pseudo stem and leaves are used for various purposes. Enset is intimately associated with the daily lives of the farmers. Owing to these facts, farmers indicated that, 'enset is everything for us'.

Over the last decades, the total area covered with enset crop has grown from 65,000 ha to about 300,000 ha. The Southern and Oromia region produce 80% of the crop.

The productivity of the crop is also very high compared to other crops but varies depending on edaphic factors, altitude, cultural practices and varietal differences. Actual fresh *kocho* yield of enset reported by CSA (1997) was 28.01 and 25.93 kg/plant in Oromia and SNNP regions. From these figures the national average actual '*kocho*' yield in tons ha^{-1} $year^{-1}$ was found out to be 11.87, assuming 2222 enset plant ha^{-1} and also reported the national average yield to be between 7.41 and 11.95 tons ha^{-1} $year^{-1}$ assuming 2000 plants ha^{-1} The average *kocho* yield of released enset varieties was 10 to 31 tons ha^{-1} $year^{-1}$(Table 2). CSA (2015) also reported that actual fresh yield of *kocho* yield of enset was 26 and 24 kg/plant and the national average to be between 11.5 tons/ha. Fresh yield potential of *'kocho'* may go up 150 $tonsha^{-1}year^{-1}$ assuming growth period of 3 years and plant population of 2500 enset plants ha^{-1} (calculated from total dry biomass which is 30% of the total fresh total biomass with harvest index of 0.5)

The amount of food attainable from 50-60 Enset plants per year could provide enough food for an average family of 5-6 persons. Enset products are available throughout the year as *kocho* and can be stored in pits for long periods of time without spoilage. These all shows how fast enset cultivation is expanding and farmers are getting more relied on the crop in the changing climate to satisfy their needs.

Table 1.Area, Production and Yield of Enset crop for Private Peasant Holdings for Meher Season 2015/16 Ethiopia

	Zone/ Region/National	Number of trees harvested	Production In Quintals		
			Amicho	*Kocho*	*Bulla*
	Ethiopia	112,522,152	23,821,849.47	28,329,103.94	950,414.35
A.	S.N.N.P.R	77,032,108	17,220,257.28	19,935,121.40	589,993.22
1	Gurage Zone	2,894,268	831,678.13	865,877.78	33,059.91
2	Hadiya Zone	2,703,039	590,662.03	622,029.31	60,567.01
3	Kembata T/ro Zone	1,463,828	17,404.11	24,984.73	947.96
4	Sidama Zone	39,092,279	9,834,586.49	9,422,838.03	294,456.75
5	Gedio Zone	7,776,231	3,003,975.22	3,421,855.40	61,909.36
6	Wolayta Zone	2,014,068	444,343.35	476,065.62	46,910.55
7	Sheka Zone	6,385,174	931,646.82	2,786,619.67	15,486.49
8	Kaffa Zone	6,263,281	35,642.69	152,250.85	3,126.45
9	Gamo Gofa Zone	2,977,505	45,511.31 *	78,975.41	5,423.93
10	Bench-Maji Zone	412,976	43,344.01	99,627.53	926.4
11	Yem Special Wereda	282,845	-	168,750.88	6,529.44
12	Dawro Zone	2,455,935	593,772.08	1,087,415.75	-
13	Konta Special Wereda	230,987	81,552.52	103,337.63	-
14	Siltie Zone	767,020	446,757.09	304,825.98	23,917.08
15	Segen Peopls's Zone	813,126	319,381.44	319,669.85	36,731.89
B.	**Oromia Region**	**35,263,883**	**6,601,592.20**	**8,393,982.54**	**360,421.13**
1	Jimma Zone	5,934,782	207,207.23	25,181.88	1,551,164.80
2	West Shewa Zone	861,516	265,786.74	380,214.29	14,415.55
3	Borena Zone	1,024,398	306,338.71	350,366.85	7,936.80
4	South-westShewa Zone	2,474,999	495,358.68	543,767.82	59,975.48
5	Guji Zone	5,495,623	1,318,146.01	1,440,028.85	75,167.76
6	West Arsi Zone	18,120,920	4,008,754.82	4,128,469.93	177,743.66

Source: Central Statistical Authority (2015/16). Area of production of major crops. Agricultural Sample survey 2015/16 (2008E.C.). Report on Land Utilization (private peasant holdings). Volume I. Statistical Bulletin 584.

Table 1.Average quantitative values of the six released varieties

Character	YANBULE	GEWADA	ENDALE	KELISA	ZERITA	MESENA
Pseudo stem height (m)	2.35	1.72	1.98	1.6	1.66	1.58
Pseudo stem circumference (m)	1.44	1.22	1.3	1.27	1.32	1.13
Leaf height (m)	4.9	4.1	4.33	3. 6	3.99	3.52
Leaf width (m)	1.1	0.9	0.88	0.84	0.85	0.84
Leaf number	12	11	11	11	12	11
Unsqueezed *Kocho* (t/h/y)	31.49	22.75	26.16	23.13	24.58	19.81
Squeezed *Kocho* (t/h/y)	21.12	15.13	17.47	15.39	16.39	13.12

Source: Mikias Yeshitla and Zerihun Yemataw (2012). Past Research Achievement and Existing Gaps on Enset (Ensete Ventricosum (Welw.) Cheesman) Breeding. In Mohammed, Y., Tariku, H., (eds.).

Food and Nutrition

Enset is one of the potential indigenous crops for food production can be grown everywhere in Ethiopia. The major foods obtained from Enset are *kocho, bulla* and *amicho*. The enset cultivation system is economically viable and is one of the few successful indigenous crops that have become sustainable in the agricultural systems. It is sustainable and has been providing foods for humans for generation from the same plot and maintains the quality of life of the people.

Nutrition content of enset

Enset plants produced much more energy per unit space and time compared to other high energy producing crops. The average energy production rate from enset was about 286 and 172% higher than that of cereals, root and tuber crops. The main future of enset foods is their high energy value (1410-1950k) per 100 g dry matter of *kocho* and (1580-1850k) per 100g dry matter of *bulla,* derived almost entirely from carbohydrate. Fresh *kocho* contains 47-62 % moisture per 100g fresh weight. The approximate composition of *kocho* per 100 g dry matter is: 1.1-2.8g protein, 95-98g carbohydrate, 0.2-0.5g fat, 2.3-6.2g fiber, 1.7g ash, 60mg calcium, 68mg phosphorus, 7mg iron, 0.06mg thiamine, 0.08mg riboflavin, and 0.6mg niacin. The moisture content of *bulla* ranges from 44-55 g per 100g fresh material. The approximate composition of *bulla* per 100 g dry matter is: 0.4-0.8g protein, 93-98g carbohydrate, 0.2-0.4g fat, 0.6-0.8g fiber, 0.2g ash, 91mg calcium, 44mg phosphorus, 5.8mg iron, 0.06mg thiamine, 0.04mg riboflavin, and 0.2mg niacin.

Economy

Agriculture and allied activities had been and will continue to play a significant role in the Economic life of Ethiopia in various aspects. The first contribution that agriculture makes in economic well-being of the nation is to the supply of food. Eighty Five percent (85%) of the national population is engaged in agricultural activities providing food to themselves and the rest of the population. Enset is the most widely used staple food crop for millions of people living in South and Southwestern Ethiopia. It plays a central role in the economic life of the South and Southwestern people, who rely on it. It gives a higher and more dependable yield than any other known crop.

Domestic Consumption

Enset is a multipurpose crop which is utilized for human food, animal feed, medicinal or ornamental uses. Farmers indicate that Enset is their food, their cloth, their house, their bed, their cattle feed and their plate. It has high significance in day to day life of the peasant households cultivating this crop as staple food. A large household can be supported by enset grown on a limited area of land. It has been articulated that the amount of food obtained from 50-60 enset plants per year could be enough for an average family of 5-6 persons. Enset guarantees food security and stability to the household economy in that the processed produce can be stored for a long time. In addition, the live plant can be maintained on farm and harvested any time when the need arises. It can be harvested and consumed before it is matured and these qualities of the crop have in part contributed to

the fact that enset areas are not characterized by a history of famine. The last five years (2010-2015) CSA report indicated that the produce from enset has increased by three-fold from 694,810 to 2,724,214 tons of *kocho* in 2010 and 2015, respectively (Annex 1). These all shows how fast enset cultivation is expanding and farmers are getting more relied on the crop in the changing climate to satisfy their needs. The market demand for enset nowadays is increasing as the consumption of *kocho* and *bulla* has widely expanded to even big cities such as Addis Ababa. According to the local people in enset areas, they are increasing their production as the demand and price for the products are rising, despite the increase.

Enset fiber is the by-product of Enset that is left after decorticating the leaf sheathes. Enset fiber is used for making bags, ropes, twines, cordage, and mats. Its strength is found to be equivalent to the important fiber crop, *Musa textiles* (abaca) and serve as a valuable raw material in local industries. Some Enset clones are known by farmers to have medicinal value for both humans and animals. These clones are claimed to heal bone fractures, are used for treatment of diarrhea and delivery problems i.e. assisting to discharge the placenta. The fresh and dried leaves of Enset have various uses. They are used as food wrappers, serving plates and pit liners during *kocho* storage. Dried petioles and midribs are used as fire wood, to make mats and as tying materials. In the dry season, the fresh leaves are used as cattle feeds. It therefore contributes enormously to food availability and economic sustainability.

Supply of raw material for local agro-industries

Enset is processed to produce both edible and non-edible products. *Kocho, bulla amicho* are products used for human consumption while the byproduct such as fiber remaining after kocho and bulla extraction are an excellent source for fiber and starch industry. The edible components bulla used as starch for textile, paper and adhesive industries and many other industrial products. Moreover it can be used as alternative starch in pharmaceutical industries. The crop also produces high quality fiber comparable to Abaca fiber; world class fiber, which is used for variously purposes depending on the social and cultural facets of communities. Even though, more than 600tons of enset fiber supplied per year to local factories it covers only 30% of the demand (Brandt SA, Spring A, Hiesch C, McCabe ST. Ethiopia has great potential to make use of enset fiber to develop products such as food grain carry bags, starches for textile, chemical and food industrial sectors and garment making .The utilization of enset in various products development save the foreign currency and also helps to increase the export potential of Ethiopia by using AGOA and COMESA export opportunities. Thus, enset products such as starch and fiber potentially supplement as raw material requirement of agro-processing industries augmenting foreign currency balance of the country.

Socio-cultural significance of enset

Socially, people in the south and Southwestern parts of the country not only depend on enset for food and cash, but also consider it as part of their cultural heritage. They have a

strong attachment to the crop. Many farming households grow enset for economic as well as non-economic purposes. According to Murdock (1959), a system of social, economic and ritual practices has developed around the cultivation of enset. The Gurage people, for example, use it for purposes such as medicine, compensation payment, and ritual offerings. Among the Gamo highlands, rituals associated with birth involve the use of a particular clone of enset.

Environmental sustainability

Besides food and fiber products, enset plays a very important environmental role. It protects the soil from erosion and runoff, it serves as shade and improves the microclimate for the undergrowth, and the litter from the leaves and other parts improve soil fertility. Unlike annual plants, a small portion of the biomass is taken out of the system during harvest, while the largest portion is returned directly as litter or indirectly through the manure. In general, enset has ideal attributes for low-input sustainable agricultural production systems: It is high yielding; it can be harvested any time once it is about four years old, it doesn't require external inputs, it protects and/or enhances the environment, and it has multiple functions. It is, therefore, no wonder that it has been supporting a very dense population for a long time. Because of its contribution to food security and environmental resilience, enset has received attention from researchers and development workers over the last few years.

Enset can be inter-cropped with many other crops (e.g. coffee, taro, vegetables, and yam) that need canopy, while there is no demonstrable competition effect on nutrient utilization. It provides a favorable microclimate as a shade tree when used in intercropping with coffee.

Enset contributes for higher reduction of losses of plant nutrients particularly nitrogen loss through leaching as compared to annual crops and it is a sustainable system with regard to maintaining the soil fertility. Soil fertility is maintained and even increased around the garden area of Enset and taro fields. Enset is a manure loving plant and hence it integrates well with livestock production.

Assessment of External and Internal Environments

Assessment of External Environments

General external situation/environments (PEST+)

Under the general external situation, analysis was made on opportunities and challenges that based on political, economic, socio-cultural, technological/technical, and environmental (PEST +) dimensions. Systematic analysis of these factors would help to have better understanding on the big picture of external factors affecting either positively or negatively and thus to craft the strategy so that it would make best use of the opportunities created by the positive influences and conversely to be cautious about the

negative influences they pose or systematically address the challenges to overcome their obstruction.

Political dimension: Assessments with the political points of view were made whether the strategy is line up with the national, sectoral and institutional policy, strategy and regulatory/legal frameworks and priorities. Since the adoption of the Agricultural Development Led Industrialization (ADLI) by the government of Ethiopia, all the policy and strategy frameworks and development programs recognized agriculture to be the engine of Ethiopia's economic growth and development. Again, food and nutrition security and climate resilient is one of the government policy and gives priorities to crops with these potentials. Moreover, the current GTP II which provides even greater emphasis to industrialization places greatest priority to those agricultural sub-sectors fostering supply of raw materials for the growing agro-industries and import substitution. Enset crop has unexploited potential to contribute towards food and nutrition security, climate resilience and industrial input substitution. Therefore, so many opportunities are set forth by the policy environment to promote research and development of the enset crop. As conducive the policy and legal frameworks put in place, there are also a number of challenges that may surface in due course.

Economic dimension: the great demand for food & nutrition security to continuously growing population and the need for industrial import substitution in line with its high yielding and multiple purposes potential create the opportunity for the enset crop to thrive. Such an increase in the demand side will be the motivation for both the farmers and processing industries to increase their outputs. The research has to; therefore, keep pace with the need of the farmers to increase production mainly through increasing productivity and minimizing pre and postharvest losses; while at the same time meeting the demand for food and nutrition security and raw materials for the industries to fulfill their requirements in quantity and standard quality.

With the nature of its wide genetic diversity, various agro-ecologies adaptability, new potential areas to grow, high productivity and good nutritional compositions; enset will support the country to fulfill food and nutrition security and import substitution demand. Enset has even more the potential to be export commodity. Currently, more than 20 millions of people in the country use it as staple food crop. It is also used as animal as feed at dry weather condition and industries like "*meher kacha*" used its fiber as input for the production of strings and sacks. Also there are some factories that extract starch from enset *bulla* that used as input for different industries. The existing economic opportunities, however, are not without posing some challenges that the research team needs to be cautious about or address during the coming years.

Socio-cultural dimension: Ethiopian farmers; especially south and south western parts of the country, have long culture of growing enset crop. Ethiopia is the only country that uses enset as food crop in the world. Therefore, like the other indigenous crops, it is the identity crop of the country. In most case enset is cultivated around homestead and

considered as a grace for their residence that increases the aesthetic value of the environment. Beyond food sources enset is used as an indicator of wealth status and working strength of the farmers in the community and its farming communities used enset as a potential source of feed for their animals, constructing materials, medicinal, ornamental crop. However, the above mentioned opportunities to enset production sustainability, there are socio-cultural challenges; like attitude of none enset production society on enset production and products together with lack of harvest and post-harvest mechanization, that limit the expansion of its production in to new areas. It is thus essential for the research team together with its key stakeholders to unravel the opportunities that it can make use of and challenges that it has to face up in order to address or change the perception of the farming society that growing enset should be considered and handled as such to be economically, socially, environmentally profitable, viable and sustainable venture.

Technological dimension: Outstandingly peculiar feature of enset is the fact that right after production the produce has to be for utilization as food. However large amount of enset fiber product is used at house hold level for making rope and different furniture's; like mats, bags, it is taken to factories for the production of strings, sacks. The industrial sector processing fiber in Ethiopia has used enset fiber as input. What has not changed much is the rate at which the domestic supply of fiber is much less than the demand of the factory.

Environmental dimension: Enset has wide range of bio-diversity and ability to adapt wide range of agro-ecology. It has also considerable carbon absorption nature that contributes towards climate resilience. While the country is a natural home for enset crop it is also the locus of genetic diversity for others. Such a diversity of ecological factors and crop types, on the other hand, provides a fertile ground for range biotic agents such pathogens, insect pests, weeds and other menaces to co-evolve with and survive on the crops against the interest of man. The damages from these biotic factors coupled with climatic and edaphic factors hindering normal growth and potential of the crops are among the primary issues that the research team would target to address. It is therefore, rational to distinguish what opportunities these environmental factors could offer in order to take advantage of them while at the same time to be prepared to tackle the challenges they may incur.

Stakeholder analysis /Operational External Environment

The need for innovative research in enset production system has been highlighted by range of stakeholders. Assessment of potential stakeholders has paramount importance for joint planning and collaboration for successful implementation of envisioned milestone of the sector. The key stakeholders with their role and responsibilities are briefed as follows (Table 3).

Table: 3.Lists of stakeholders with their roles.

Stakeholders	Roles
Ministry of Agriculture	• Provision of logistic support • Capacity building (infrastructure, training, laboratory facilities, …) • Community mobilization, enhancing overall facilitation
The Ethiopia Agricultural Research Institute (EARI)	• Allocation of resources • Capacity building (infrastructure, training, laboratory facilities, …) • Research program facilitation, organizing of multi-stakeholders platforms • Monitoring and evaluation of research program
Southern Agricultural Research Institute (SARI)	• Coordinating research on national enset research project • Allocation of resources • Capacity building (infrastructure, training, laboratory facilities, …) • Research project facilitation • Organize multi-stakeholders platforms • Monitoring and evaluation
Areka Agricultural Research Center (Center of excellence)	• Coordinating research on national enset research project • Conduct enset research • Research project facilitation • Establish and organize multi-stakeholders platforms • Facilitate cooperation among collaborating institutions • Joint research • Germplasm maintenance and exchange • Technology promotion • Monitoring and evaluation
Kulumsa, Jimma, Holleta, Bonga, Awassa, Tepi, Ambo, Worabe Agricultural Research Center (Core Collaborating Center)	• Conduct enset research • Joint research • Facilitate cooperation among collaborating institutions • Germplasm maintenance and exchange • Technology promotion
Regional agricultural research Institutes (RARIs)	• Strong collaboration • Allocation of resources • Capacity building (infrastructure, training, laboratory facilities, …) • Facilitate and implement regional research programs • Organizing of multi-stakeholders platforms • Monitoring and evaluation of research program
Universities	• Training (Short and long term) • Cooperation and implement research projects • Monitoring and evaluation
Ethiopian Biodiversity Institute	• Provision of financial support • Collaboration and implement research projects • Monitoring and evaluation
Commission of Science and Technology	• Provision of financial support • Collaboration in research projects • Monitoring and evaluation
Agricultural Transformation Agency (ATA)	• Technical support • Collaborating for research
CGIAR centers and External collaborator Universities (Exeter, Leister)	• Provision of Technical and financial support • Capacity building (infrastructure, training, laboratory facilities, …)

	• Collaboration and implement research projects
Rural technology Centers	• Training (Short term) • Collaboration and implement research projects; like for improved farm implementing equipment
NGOs	• Provision of financial support • Collaboration in research projects • Capacity building (infrastructure, training, laboratory facilities, …) • Scaling out of improved technologies
Privet sectors	• Cooperation in research project • Active engagement enset product • Technology multiplication
Mass Medias	• information dissemination and community sensitization
Farmers (Community based organization)	• Full participation in research project planning and implementation • Engage community mobilization activities • Organizing farmers groups,

Benchmarking

As pointed out earlier, Ethiopia home land and has a considerable potential for growing enset not only in terms of suitability of the existing ecological settings but also a number of other factors discussed in the preceding sections including favorable policy, economic, socio-cultural, technological and environmental circumstances. As part of the external environmental factors, it is also a strong exercise to examine the potentials of the crops which can and should be exploited by drawing lessons from existing indigenous knowledge and other countries that have advanced levels of research achievements on related crops; like abaca for fiber production. As enset is indigenous crop, existing indigenous knowledge and the results of previous research works are considered as bench mark.

In addition, countries like Uganda are given us good lesson to enst bacterial wilt management; as they achieved incredible result on bacterial wilt management on their staple food crop; banana.
For Fiber south east Asians like Philippines and Indonesia that they have good achievements on producing and exporting abaca fiber to the world market.

For starch production; the experience of starch privet company that extract enset starch in our country and Germany, Netherlands, Poland that produce starch from potato are our bench marks.

Assessment of Internal Environments Strategic Issues Facing the Commodity

Assessment of internal environments is an introversive process whereby the research team examines the capacity that exists within the EARI system and can readily be utilized by the team to deliver outputs. Such a capacity that is readily available for the team denotes the strength of the team while the capacity which is required to deliver the outputs but falls short to exist symbolizes the weakness of the team. Assessment of the

internal environment is thus about precise identification and articulation of strengths and weakness of the research program. Capacity in this context encompasses a wide array of topics including institutional capacity which signifies the available or lacking human, physical and financial resources; technical or technological capacity and organizational capacity which deals with the questions of functional integrations within and between disciplines to forge complementarities and synergies. Below are briefly discussed the elements of internal environments examined to synthesize summaries of the Strengths and Weakness provided in Table 4.

Resources

The human, physical and financial resources have an influential power on program implementation, coordination and administration. Therefore, the level of human resources capacity, financial capacity and the physical resources available and lacking were assessed and tabulated as strengths or weaknesses.

Inter- and intra- disciplinary integrations, complementarities and synergies

The success of enset research depends on integrated and combined efforts of various research disciplines and sectors. In addition to that of the mainstream disciplines; breeding, agronomy, crop protection, socioeconomics & extension and food science, there are clear possibilities of realizing complementarities and synergies by working together with experts of other fields. Important among these potentially potent areas of integration include: Agricultural-Biotechnology Research, Agricultural and Nutritional Research Laboratory, Land and Water Resources Management Research, Enset-processing and mechanization, Technology Multiplication and Seed Research, Climate and Geospatial, Livestock Research and ICT. Assessments were thus made whether or not there could be integrated for synergies with these compelling areas of research.

Technologies

As has been said earlier, a concerted research on enset started before three decade's and to date 6 improved varieties were released (see Table 2). Suitable agronomic recommendations were established. The major diseases and insect pests of the crop were identified and their management measures were worked out and established. Whether or not the changes brought about by these technologies are in balance with the expectations are evaluated to point out and build on the strengths and draw lessons from the weaknesses.

Organization, implementation and geographic coverage

Lack of strong systems and procedures (i.e., organizational capacity) at different levels is an area of capacity impairment that affects effectiveness. Limited intra- and inter-institutional linkages are also sources of limitation for rapid progress. Organizational strengths and weaknesses that would correspondingly make the growth of enset research to take upward or downward trend were analyzed from the center-level, institutional level and national level perspectives.

Strengths, Weaknesses, Opportunities and Challenges by the Research Themes

Table 2. Summary of analyses of external and internal environments reflected in terms of strengths, weaknesses, opportunities and challenges pertaining to the different thematic research areas

Thematic area	Strength	Weaknesses	Opportunity	Challenge
General	• Sufficient working premises (offices and experimental fields at center level); • There is a core research team representing the different disciplines at the coordination center; • Recognizing enset as a national commodity will draw emphasis and attentions of decision makers; • The culture of research collaborations to conduct joint reviews and planning, multi- location trials, adaptation trials etc. among research centers.	• Lack of skilled human power especially in modern tools of crop improvement, protection, post-harvest and quality analysis; • Limited staff time for disciplines other than breeding and agronomy; • Turnover of experienced researchers; • Lack of standards or protocols for utilization of quality lab facilities (GC, NIRS.,; • Lack of self-contained lab, green house and standard store and • Poor linkage of the research with other stakeholders along the value chain.	• National focus on transformation of the agricultural sector through diversification and market-led production of high-value crops; • Encouraging Government policy for the establishment and expansion of agro-industries demanding raw material with high standard quality and the potential of the crop to provide industrial raw materials with competent quality; • High yielding ability, wide adaptability, and multi-purpose nature of the crop; • A large volume of fiber and starch have being imported annually and thus there is a huge potential for import substitution; and also import substitution is high GoE's priority; • High potential market for enset products in the country and • There are many institutions like universities which have the capacity to undertake basic and applied researches.	• Limited adaptation by non enset farming community. • Lack of market linkage • Lack of harvesting technology

Breeding and genetics	• Presence of relatively experienced breeders at the coordination and other center	• Limited support from CGIAR centers and lack of modern breeding laboratory and green houses.	• The country is center of origin and diversity for enset	• Enset genetic erosion due to EBW, competition from other crops and climate change
	• Availability of biotechnological laboratories at institute and SARI level	• Limited basic research on enset exists to serve as a basis for further exploration	• Diverse enset agro-ecology and farming system	• Shortage of field and laboratory supplies and consumables
	• Availability of field for screening of diseases of enset	• Limited applied research in enset improvement	• There is collection of germplasm material at the Ethiopian Biodiversity Institute (EBI)	• Inadequate facility and frequent training for laboratory technicians
	• Maintenance of more than 500 farmers variety and production of breeder seedlings	• Released varieties do not adequately address different use value and adaptation to various agro-ecologies.	• Availability of strong collaboration in training with international research centers	• Lack of laboratory consumables for quality analysis
	• Recent emphasis in multi-disciplinary research approach by the national and regional institutes (EARI); • Availability of varieties for kocho yield and quality; • Increasing focus on pharmaceutical and industrial uses of enset and • Presence of national and regional biotechnology laboratory and some trained manpower.	• Lack of genetic information (e.g. gene actions and inheritance of traits) to base on and plan genetic gains to be attained in order to improve disease resistance; • Use conventional method for variety development is so lengthy (it needs 7-10 years for variety release); • Lack of capacity in bioinformatics, genotyping, sequencing and their utilization in molecular breeding and • Limited focus on enset nutritional, pharmaceutical and industrial quality.	• Availability of diverse enset genetic resources (within & without); • Availability of decentralized research on enset by regional, federal and higher learning institutes; • Availability of modern biotechnological tools and facilities elsewhere to adopt, adapt and use and • Reproductive nature of the crop (Asexual and sexually propagated).	• Shortage of land and facilities for seedling multiplication; • Limited manpower in biotechnology at commodity base; • Difficulty for introduction of other Ensete species and • Insufficient genetic resource collection and management.

Breeding and genetics	• Increasing focus on enset production in marginal environments (low moisture areas)	• Breeder seedling insufficient quantity; • Limited technologies for low input management and marginal environments; • No variety released based on their animals feed quality and • Variety development programs are weakly linked with other research multidiscipline.	• Presence of policies and regulations on germplasm exchange, introduction of foreign plant material and plant quarantine; • Encouraging policy and Public investment for introduction and adaptation.	• Lack of capacity to identify resistance genes, mechanism of resistance and incorporate it in developing new varieties.
Agronomy and crop physiology	• Recent emphasis in multi-disciplinary research approach by the national and regional institutes (EARI) ; • Presence of relatively experienced agronomist at the coordination and other center; • Experiences in cropping systems research with legumes and other horticultural crops from which lessons could be drawn exist and • There are research centers with many years of experience in dry land agriculture.	• Blanket recommendations and coverage of only pocket areas; • Limited capacity to employ precision agriculture; • Limited focus on system productivity (enset-soil-livestock interaction); • No agronomic packages for low moisture areas; • Lack of integrated agronomic packages for all enset growing agro-ecologies; • Limited focus on physiological research and • Lack of training and experience sharing programs in crop physiology.	• Enset has long well established farming system;. • The culture of producing enset with integration with other crops and animals; • The existence of diverse agro-ecology suitable for growing enset are being cultivated by more than 20 million small farmers in Ethiopia; • Availability of compatible crops with enset in the production systems and • Government policy and focus on full package for increased productivity and production to realize food security.	• Climate change and natural resource degradation (Drought and heat stress); • Complex physiology of perennial crops in response to varied agronomic practices (eg. leaf removal) and production systems and growing AEZs; • Proper placement of resources to pursue market-oriented production while promoting some cropping systems like mixed cropping, etc. needs careful balancing and • Less focus on human power development programs in the area of crop physiology.

Agronomy and crop physiology		• Limited utilization of crop modeling tools and less focus on training in modeling; • The agronomic recommendations available may not suit for different agro-ecologies and farming system.	• Availability of physiological facilities elsewhere for application to incorporate physiological traits used for enset improvement program; • Wide availability and applicability of crop modeling tools to predict future crop production scenarios and • Presence of full time and working agronomist in the coordinating and other centers.	• Lack of equipment's and training programs in physiological research; • Inherent tradition in different agronomic practices; • There is lack of technical knowledge from the side of extension service providers (Wereda experts, DAs and SMS) on enset production
Soil and Water Management	• Attention given to organic agriculture (manure, compost, vermicompost); • Use of soil map based recommendation; • There exist strong soil and water management research facilities including well experienced personnel and equipped laboratories; • The research team has the experience of preparing packages of optimum soil fertility management options (fertilizer rates, mode and method of application) and • Availability of inorganic and organic fertilizer rate recommendation.	• Limitation in determining appropriate rate of organic fertilizers (compost, vermicompost, manures etc); • Limited recommendation for problematic soils; • Lack of recommendations on enset with other crop, animals and soil fertility management; integrated production system; • Recommendations on integrated soil fertility management appropriate for growing enset in different agro-ecologies are not available and • The soil fertility management recommendations are by and large general not tailored to specific agro-ecologies and farming systems.	• Availability of organic and inorganic fertilizer sources; • Attention given to micro nutrient fertilizers; • Presence of full time and working expertise in the coordinating and other centers; • There have now been established fertilizer blending plants producing and distributing fertilizers of various mixes including both macro and micro elements.	• The culture of not using inorganic fertilizer for growing enset; • High requirement for investment in soil sampling and analysis; • Lack of short term training programs or Technical Assistance for soil sample collection and analysis.
Crop protection	• Attention given to periodical survey and surveillance of major enset diseases and	• Lack of modern protection research facilities and highly trained technical staff;	• Existence of wide range of diverse wild enset out of the country; • Encouraging policy on protection;	• Climate change and variability leading to disease dynamics, insect pest epidemics and and

	insect pests; • Availability of relatively better wilt tolerant varieties against EBW; • Few studies on botanicals; • Availability of core team members of crop protection at coordination & collaborative centers; • Availability of relatively better basic knowledge on major disease and insect pest biology, and diversity; • Existence of recommended effective integrated cultural practices that enable to manage enset (EBW); • Surveys conducted in some enset growing areas; • Efforts made to develop varieties with resistance to major disease (EBW); • The existence of a research center working on crop protection including weed sciences can provide back up and • Economically important disease and insect pest of enset were identified.	• Limited focus on monitoring and pathogen evolution; • Limited promotion and adaptation of this recommended disease management practices by farming community; • Less attention given to occasional disease and insect pest survey in enset producing areas; • Less focus on identification of resistance genes of disease and insect pest and using for variety development; • Limited expertise for bio-control of diseases and insects; • Less frequent surveys for weed flora density and abundance and • Limited knowledge on diseases and insect pests identification, their biology and epidemiology.	• Existence of established government agricultural organizations up to *kebele* level and; • Regional and federal government give attention for community mobilization; • Availability of crop protection researchers in the coordinating and collaborating centers and existence of plant health clinics at region level; • Molecular laboratory and partner institution working on diversity and the information on related crops (eg. Banana); • Availability of enset landraces which confer genes for resistance against diseases; • Availability of molecular tools and modern approaches elsewhere; • Diverse agro-ecology suitable for enset production and • Available options for insect management (cultural, chemical, biological).	favors emergence of new enset diseases and insect pests; • Susceptibility of enset varieties to major enset disease (EBW); • Lack of complete resistant clone for enset bacterial wilt ; • Resistance of farmers to implement recommended cultural and sanitary control measures for EBW; management • Ineffective quarantine/regulatory system and surveillance and • Knowledge and skill gap on major enset diseases and insect pest biology and epidemiology and lack of strong and well equipped protection laboratory.

GIS and agro-meteorology	• Preliminary works for enset disease map	• Lack of crop suitability map, seasonal forecast and geospatial analysis information for production and marketing of enset crops	• Diverse agro-ecology for production of different types of enset for high yield, nutritional and and other use value	• Global climatic change affecting the suitable agro-ecologies turning them into non-suitable
	• GIS and agro meteorology research units are established in most research centers		• Sophisticated GIS and agro-meteorology technologies are available worldwide	• Big technological and research capacity gap and the technologies are expensive
Technology multiplication and seed research	• Established community seed production schemes for fast multiplication and outreach; • Availability of seed research discipline; • Six enset varieties have been developed and released along with suitable agronomic; recommendations • Closeness of the coordination center to the major enset production areas of makes to easily evaluate merits and the need for new technologies and • Conventional propagation and tissue culture protocols are developed for enset.	• Less focus on pre-basic seedling multiplication in required quantity; • Limitation in technical support to community producers in quality seed production; • Limited focus on enset seedling health and quality; • Less focus and lack of awareness on diseases and pests and • Lack of micro-propagation techniques and protocols for enset planting material multiplication.	• Strong demand from stakeholders for improved seedling for new areas; • Availability of privet planting material producers in the country and • Encouraging policy and public investment on technology multiplication.	• Shortage of land and appropriate facility for early generation seedling production; • Limited facility and expertise in seed quality research.
Agricultural Economics, Extension and Gender	• At the coordination center core research team representing the different disciplines that has been established also includes researchers of socio-economics, research extension	• Limited demonstrations and popularization of enset technologies; • Limited information on the production, marketing, processing and value chains on costs of	• Variety of enset production and utilization cultures regarding preparations of variety of traditional dishes and medicine; • Use of enset products for multiple purposes in multiple ethnic groups.	• Low rate of adoption of technologies and limited use of full packages by resource poor farmers • Weakness and lack of commitment of stakeholders

	and gender;	production and efficiency and cost-benefit analysis in major producing areas. .		platform (ADPLAC)
Agricultural Economics, Extension and Gender	• Closeness of the coordination center to the major enset production areas of makes to easily evaluate merits and the need for new technologies; • EARI has adopted the policy of gender as one of the crosscutting themes to be mainstreamed in all its implementation agenda; • Availability of research extension discipline; • Strong linkage and collaboration with farmers and extension offices to collaboratively organize farmers trainings, field days and travelling workshops; • Few value chain and map studied; • Increasing attention to gender and youth in research and • Few Studies and characterization of enset based farming systems.	• Lack of communication media in local languages (fliers, extension bulletins, leaflets, production manuals and mass media); • Limited farming system characterization in some enset agro-ecologies; • Limited market promotion has been done on enset fiber even with its competent quality with abaca fiber; • Level of technology adoption and determinants for adoption of enset is not clearly known at the national level; • Lack of participatory variety selection and inclusion of farmers criteria in variety development; • Less focus and mainstreaming of gender and youth in research interventions; • Limited involvement of all concerned stakeholders in collaboratively organized field days, travel workshops and discussion forum and • Limited information on international market of fiber and starch.	• The existence of high demand for Natural fiber; • Presence of Enset fiber demanding factory; • Positive tendency for enset production as food crop by community that were not previously familiar with its production; • High productivity, wide adaptability and climate resilient nature of the crop; • Different farming system and agro-ecology; • Presence of government structures at different levels (federal, regional, zonal, district and kebele levels) and other stakeholders to support the dissemination of enset technologies; • Presence of collaborative research and development planning platform (ADPLAC); • Availability of innovative and champion (model) farmer and • Availability of many actors (governmental, NGOs, agro-industries etic) in enset sector.	• Dynamism of enset production system (area shrink due to competition from other crops and climate change); • Lack of commitment from all value chain actors to hold together the chain; • Limited number and capacity of starch and fiber factories and • Limited Knowledge of farmers on quality fiber, bulla extraction.

Agricultural Mechanization	• Some efforts has been made by rural technology centers and polytechnic colleges to made enset farm implements • Availability of mechanization research	• Lack of recommendations on appropriate pre- and post-harvest handling practices	• Agricultural mechanization has nationally gained momentum as an essential element of the GTP • Mechanization services	• Advanced and expensive agricultural equipment in enset value chain makes the technologies unaffordable by small holder growers
Agricultural Mechanization	• EIAR has a solid experience in agricultural mechanizations and plenty of prototypes of farm implements suitable for small-scale agriculture	• Limitation on multiplication of prototypes of improved processing implements	• Presence of enterprises and farm machinery suppliers engaged in providing	
Agricultural Quality and Nutrition Research Laboratory	• Some studies on macro and micronutrient composition of enset varieties; • There is a relatively well equipped central quality laboratory at HQ and • Presence of food science and post-harvest researcher in core team at coordinating center.	• Limited information on post-harvest handling techniques and food process; • Limited information on indigenous knowledge on making variety food staffs prepared form enset at different culture; • Limited research on nutritional qualities of released varieties; • Little is known of inherent macro and micronutrient content of released enset varieties and local landraces and • Less focus on macro and micronutrient fortification.	• Rich Indigenous knowledge on making Variety food staffs prepared form enset at different culture and on post- harvest handling; • Multiple uses of enset and increasing demand for enset food products; • Favorable policy incentives for agro-processing industries for export market and • Increased local demand for processed enset products.	• Malnutrition and health defects related to un-balanced diet from consumption of few dishes; • Lack of investment in sector specific infrastructures and logistics.
Capacity building	• Efforts to retain the experienced senior staff for mentorship; Focus on modernizing the research producers by using modern farm tools (Processing	• Lack of joint review among different research disciplines; • Inadequate integration and cooperation of researchers and • Inefficient utilization of the allocated budget for running the	• Availability of young researchers in the research system • Government and donors support to capacity development	• Lack of conducive working environment in the research system; • Continuous turnover of experienced research staff; • Limited frequent training (long-

	devices.	enset research, and procurement of the facilities.		term and skill) to develop the skill and knowledge of research staff and • Inefficient budget release procurement system for utilizing the available resources.
Capacity building	• Project development for funding by donors	• Limited mentorship	• Presence of research facilities (national biotechnology laboratory, nutrition laboratory) and service given by different institutions	• Limited facility in enset planting material production; • Lack of greenhouses; • Limited laboratory equipment for physical and chemical analysis, physiological, pathological and quality tests; • Shortage of offices and laboratories and • Shortage of vehicle.
Cross cutting themes	• EIAR has a strong capacity to undertake ICT-based information compilation, dissemination, knowledge management and networking to promote the enset sub-sector and • EIAR has adopted the policy of climate change as one of the crosscutting themes to be mainstreamed in all its implementation agenda.	• Lack of a central data/information base that could be accessed through the network on what facilities a given center, research program or team is equipped with, what technical support the facility could provide for fellow researchers from other centers; • Weak linkages and inadequate scientific for such as ICT-based networking, regular discussions on specific research topics, projects and technologies Climate change (this is especially important in marginal areas where	• Recognizing the role Information and Communication Technology (ICT) can play in development, the GoE adopted the ICT policy and strategy; a significant progress was made in communications network in the country since the enactment of the policy and • The MoANR has since long ago adopted strategies and programs such as SLM that are being implemented nationwide.	• Impacts of climate change are associated with changes in the frequency, intensity, and predictability of rainfall and water availability with consequential effect of decreased agricultural production and food shortages and • Technologies enhancing adaptation and mitigation such as cropping systems etc. are merger.

		drought is an imminent problem. Also is becoming a threat the emergence of new pests or dynamic shift of those never been major pest earlier); • Lack of information and technologies and • Specifically tailored to address climate challenge.		

Strategic Issues Facing the Enset Commodity

Table 3.Strategic Issues (Gap Analysis) Facing the enset Commodity

Thematic areas/ research disciplines	Strategic issues
Breeding and genetics	• Limited basic research knowledge • Limited germplasm collection, conservation and characterization • Limited variety screening and development for diverse agro-ecology and uses • Narrow genetic resources base especially for specific traits (EBW resistance) • Limited application of Biotechnology tools for variety development and maintenance • Insufficient availability of breeder seedling
Agronomy and physiology	• Less information on enset cropping systems • Limited agronomic practices and techniques for different cropping systems and agro ecologies • Limited study on crop modeling • Inadequate information on crop physiology • Limited study on system intensification
Soil and water management	• Inadequate study on integrated soil fertility management • Limited study on soil fertility management for different soil types and farming systems
Crop protection	• Limited basic information on enset bacterial wilt • Limited basic information on other pests • Limited study on epidemiology of enset disease and pests • Limited information on alternative disease and pest control options (eg. Biocontrols etc) • Limited application of molecular diagnostic techniques and management aspects for economically important enset disease and pests (eg. Enset *Xanthomonas* wilt …) • Limited information on pathotype and race evolution mechanisms • Limited study on surveillance and devising management options for newly emerging diseases (e.g. fusarium wilt) • Limited research on integrated pest management
GIS and agro-meteorology	• Limited information for enset suitability map • Limited knowledge on disease and pest prevalence and distribution mapping • Limited information for enset agro-climatology and climate oriented geospatial crop modeling • No information on the effect of climate change on pest and weed intensity
Technology multiplication and seed	• Limited study on macro propagation and phytosanitory techniques

research	• Limited work on planting material multiplication • No study on quality declared seed multiplication protocol • Limited information on enset seed system • Limited work for inspection and certification of the planting materials and propagation techniques
Agricultural Economics, Extension and Gender	• Limited farming system studies • Limited value chain studies • Inadequate studies on enset marketing and technology promotion • Low focus on gender and youth-aware intervention • Limited study on enset technology adoption and impact assessment • Limited study on enset production economics (cost of production)
Agricultural Mechanization	• Limited studies on processing technologies prototype development and multiplication. • Limited study modification of existing processing technologies • Limited study on small-scale processing technologies
Agricultural Qualityand Nutrition Research Laboratory	• Limited studies on nutritional characteristics and quality related traits • Limited studies on industrial potential of enset • There is no well-developed and commercially available starter culture for controlled fermentation • Limited studies on traditional food recipes and industrial values • There is no well-developed laboratory protocols and standards • Limited study on enset Product development and Post-harvest handling
Capacity building	• Limited man power and high turn-over of staff in enset research • Low focus on human power development through short term and on-job training, longterm studies (MSc, PhD), exchange visits and mentoring or experience sharing • Limited infrastructure and facilities • Limited budget allocation, insufficient procurement procedure and delay of budget transfer to run day to day enset research • There is no web-based centralized enset resources
Crosscutting themes	• Gender • Climate change • Knowledge management

The Strategy to Address the Issue

Despite being an orphan crop, enset is supporting more than one-fifth of Ethiopian population and could be considered as a hidden treasure. Yet, it has not attracted a considerable attention from research and funding community in the past. In recent years, however, the gov't has declared enset as a food security and commodity crop and started to support the classical enset research so as to stimulate research on the crop. Agriculture anticipated continues to play the lead role to transform into industrialization in the second five-year growth and transformation Plan (GTP II) of the country.

In context of GTP II plan of the country, the agricultural sector in particular, contribution of enset a commodity could immense pertaining to its multipurpose value, industrial and pharmaceutical applications. In order to exploit the potential contribution of enset, this strategy is designed in such a way that considers the SWOC and PEST aspect of the crop. In addition, the various of organization engaged or likely to engage in enset improvement and product development, potential and previously non-enset growing areas, and strong collaboration and cross-feeding among engaged organization for concerted effort is taken into due consideration. Accordingly, it has been attempted to be client and demand-driven, gender and climate-aware, and participatory to benefit from the indigenous knowledge of farmers.

Therefore, this strategic roadmap document on enset is geared towards three coarse issues that comprehensively touches wider horizon in enset research and could potentially assist to maximize the benefit from enset cultivation and utilization. These are (1) generating basic information on enset, enset disease and pest, and enset associated topics using classical, cotemporary and the state-of-art science (2) strengthening resource capacity for enset research (3) establishing a national forum for enset research and development efforts for concerted efforts.

Accordingly, the research strategy for enset described below is based on the identified thematic areas of the identified issues for the coming 15 years by three phase intervention; short (2016-2020), medium (2021-2025) and long-term (2026-2030) interventions.

Table 4.Strategic issues and interventions

Strategic issues and their thematic areas	Short term (2016-2020) intervention	Medium term (2016-2025) intervention	Long term (2016-2030s) intervention
1. Breeding and genetics research			
Generation of basic information	• Generate basic information on • Catalogues and markers of candidate genes of agronomics importance in enset genome; • Genomic resources for enset (whole genome sequence, transcript, ESTs, protein etc), enset disease and pests, and host-pathogen interaction • Identifying molecular markers on agronomically important traits (eg. Enset Xanthomonas wilt resistance) • Genetic diversity of enset population • Genome wide association mapping for agronomically important traits • Generate basic information on floral biology, ecology and reproduction system in cultivated and wild enset.	• Continue generation of basic information on ; • Catalogues and markers of candidate genes of agronomics importance in enset genome • Genomic resources for enset (whole genome sequence, transcript, ESTs, protein etc), enset disease and pests, and host-pathogen interaction • Identifying molecular markers on agronomically important traits (eg. Enset Xanthomonas wilt resistance) • Genome wide association mapping for agronomically important traits • Enhancing enset genetic resource • Continue generation basic information on floral biology, ecology and reproduction system in cultivated and wild enset. • Undertake crossing studies	• Further continue generation of basic information on; • Markers of candidate genes of agronomics importance in enset genome • Genomic resources for enset (whole genome sequence, transcript, ESTs, protein etc), enset disease and pests, and host-pathogen interaction • Genome wide association mapping for agronomically important traits • Genetics of enset • Enhancing enset genetic resource • Strengthening generation basic information on floral biology, ecology and reproduction system in cultivated and wild enset. • Continue crossing studies
Biotechnology for germplasm enhancement	• Development and optimization of in vitro protocols for different enset landraces	• Development and optimization various in vitro protocols for different enset landraces	• Enhance mutational breeding and evaluate progenies combining with molecular tools

	• Undertake DNA transformation techniques • Undertake mutational breeding in enset (Induction of mutation using different techniques on landraces having agronomically important phenotypically well characterized enset) • Undertake identification of molecular markers linked to agronomically important traits (Eg. resistance to Xanthomonas wilt of enset) • Undertake genomic barcoding of enset cultivars	• Continue DNA transformation techniques • Strengthen mutational breeding and evaluate progenies combing with molecular tools • Continue identification of molecular markers linked to agronomically important traits (Eg. resistance to Xanthomonas wilt of enset) • Apply molecular markers in identification of cultivars identify in the process of evaluation	• Strengthen identification of molecular markers linked to agronomically important traits (Eg. resistance to *Xanthomonas* wilt of enset) • Strengthen applying molecular markers in identification of cultivars identification in the process of evaluation • Undertake marker assisted selection breeding
Germplasm collection, conservation and characterization	• Establish a mechanism for exotic enset species collection • Undertake collection of enset landrace from previously untouched or unexploited areas and conserve at ex-situ field gene bank • Undertake characterization of collections for various traits	• Undertake collection of exotic enset species • Continue collection of enset landrace from previously untouched or unexploited areas and conserve at ex-situ field gene bank • Continue characterization of collections for various traits	• Strengthen collection of exotic enset species • Continue further characterization of collections for various traits
Variety screening and development for various use value as well as for major biotic and abiotic stress	• Identify varieties for non-traditional enset growing areas • Undertake various yield trials for different use values, moisture stress and enset *Xanthomonas* wilt resistance • Undertake evaluation for industrial and pharmaceutical value of enset. • Develop varieties for EBW resistance, *kocho bulla*, fiber, *amicho,* low moisture stress	• Develop varieties for non-traditional enset growing areas • Continue yield trials for different use values, moisture stress and enset *Xanthomonas* wilt resistance • Continue evaluation for industrial and pharmaceutical value of enset • Continue variety development for EBW resistance, *kocho bulla*, fiber, *amicho,* low moisture stress	• Continue variety development for non-traditional enset growing areas • Continue yield trials for different use values, moisture stress and enset *Xanthomonas* wilt resistance • Continue evaluation for industrial and pharmaceutical value of enset • Strengthen variety development for EBW resistance, *kocho bulla*, fiber, *amicho,* low moisture stress
2. Agronomy and physiology			

Cropping systems	• Characterize and classify enset growing AEZs. • Conduct cropping system studies (crop rotaion, mixed cropping, etc.) for sustainable production of enset • Verify available cropping system technologies for different agro-ecology and farming ystem. • System intensification study for different agro-ecology.	• Continue the characterization and classification of agro-ecologies of enset • Continue conducting cropping system studies (crop rotaion, mixed cropping, etc.) for sustainable enset production • Verify available cropping system technologies • Continue system intensification study for different agro-ecology and farming ystem.	• Continue conducting cropping system studies (crop rotaion, mixed cropping etc.) for sustainable enset production • Verify available cropping system technologies • Continue system intensification study for different agro-ecology and farming ystem.
Crop physiology and crop modeling	• Conduct crop physiological studies (water use efficiency, photosynthetic efficeincy, nutrient use efficiency, stress physiology, crop growth and development) • Morpho-physiological traits associated with moisture and nutrient stresses, • Intiate crop modeling stduies in relation to climate change in different enset production systems • Initiate application of biotechnological tools for studies of abiotic stresses	• Continue conduct ing crop physiological studies (water use efficiency, photosynthetic efficeincy, nutrient use efficiency, stress physiology, crop growth and development) • Refine the study on eco-physiological traits associated with stresses. • Continue crop modeling stduies in relation to climate change in different enset production systems • Study the physiology of enset seed and plant growth and development under different AEZs. • Continue application of biotechnological tools for studies of abiotic stresses	• Continue conduct ing crop physiological studies (water use efficiency, photosynthetic efficeincy, nutrient use efficiency, stress physiology, crop growth and development) • In-depth study and exploitation of eco-physiological traits associated with stresses for different AEZs. • Continue crop modeling stduies in relation to climate change in different enset production systems • Continue study the physiology of enset seed and plant growth and development under different AEZs. • Continue application of biotechnological tools for studies of abiotic stresses
3. Soil and water management			
Soil fertility management	• Determine optimum organic and in- organic fertilizer rates, method and time of application for different enset production systems • Develop Integrated Soil Fertility management (ISFM) for different soil types and AEZs • Verify available soil fertility management technologies for different agro-ecology and farming ystem.	• Continue determining optimum organic and in-organic fertilizer rates , method and and time of application for different enset production systems • Continue development of the integrated soil fertility management (ISFM) for different soil types and AEZs • Continue verification of available soil fertility management technologies for different agro-	• Continue determining optimum organic and in-organic fertilizer rates, method and time of application for different enset production systems • Refine and validate integrated soil fertility management (ISFM) for different soil types and AEZs • Continue verification of available soil fertility

		ecology and farming ystem.	management technologies for different agro-ecology and farming system.
Crop response information	• Determine soil test-based crop response information	• Continue determinig soil test-based crop response information	• Continue determinig soil test-based crop response information
Crop water requirement	• Determine water use efficiency and optimiztion techniques	• Continue determinining water use efficiency and optimiztion techniques	• Continue determinining water use efficiency and optimiztion techniques
4. Crop Protection			
Pathology			
Basic information on enset disease	• Variability of major diseases (EBW and other) • Profiles of pathogenicity/virulence factors of major pathogens and host responses • Systemicity of EBW in enset • Start genomics information on mechanism of tolerance/ resistance to major disease (EBW etc) in enset • Beneficial microbes associated with tolerant/resistant enset or their ecology	• Continue variability (phenotypic and molecular) study of major and emerging diseases • Continue genomics information generation on enset-disease interaction • Enhanced studies on profiling pathogenicity/virulence factors and host responses identified • Continue studies on beneficial microbes associated with tolerant/resistant enset or their ecology	• Continue diversity (phenotypic and molecular) study of major diseases • Continue genomics information generation on enset-disease interaction • Enhanced studies on profiling pathogenicity/virulence factors and host responses identified • Continue studies on beneficial microbes associated with tolerant/resistant enset or their ecology
Effect of climate change on enset diseases	• Undertake periodical disease surveys in enset production systems • Study disease dynamics in relation to climate change	• Continue undertaking periodical disease surveys in enset production systems • Continue the study of disease dynamics in relation to changing climate	• Continue periodical disease surveys • in enset production systems • Continue the study of disease dynamics in relation to changing climate
Epidemiology and sources of disease resistance	• Conduct studies on epidemiology of major enset disease (EBW) in enset production systems • Screen enset genotypes against Xanthomonas races enset disease and identify sources of resistance using molecular tools • Indigenous knowledge study on disease control methods identified, documented, and tested	• Continue conducting epidemiology studies of major enset disease (EBW) in enset production systems • Continue Screen enset genotypes against Xanthomonas races enset disease and identify sources of resistance using molecular tools • Continue indigenous knowledge study on disease control methods identified, documented, and tested	• Continue conducting epidemiology studies of major enset disease (EBW) in Enset production systems • Continue Screen enset genotypes against Xanthomonas races enset disease and identify sources of resistance using molecular tools • Continue indigenous knowledge study on disease control methods identified, documented, and tested

Race identification	• Initiate race evolution studies on major enset diseases • Conduct race and pathotype analysis of major enset diseases • Identification of local growth media for EBW Pathogen isolation	• Study and uncover the mechanism of pathotype or race evolution in major enset diseases using standard procedures • Continue race and pathotype analysis of major enset diseases	• Continue studying and uncovering the mechanism of pathotype or race evolution in major enset diseases using standard procedures • Continue race and pathotype analysis of major enset diseases
Molecular studies on disease resistant traits	• Initiate identification of genes for durable disease resistance using marker assisted selections (MAS)	• Continue assessing and identifying genes for durable resistance using marker assisted selections (MAS)	• Contiue assessing and identifying genes for durable resistance using marker assisted selections (MAS)
Quarantine	• Early detecting tools for deadly enset disease (eg. EBW) and other disease imported/developed	• Continue early detecting tools for deadly enset disease (eg. EBW) and other disease developed	• Advanced detecting tools for deadly enset disease (eg. EBW) and other disease imported/developed
Integrated disease management	• Identify effective integrated disease management options	• Continue identification of effective integrated disease management options	• Continue identification of effective integrated disease management options
Entomology	•	•	
Effect of climate change on insect pests	• Undertake enset insect pest surveys periodically in enset production systems • Study insect pest dynamics in relation to climate change	• Continue undertaking enset insect pest surveys periodically in enset production systems • Continue studying insect pest dynamics in relation to climate change	• Continue undertaking enset insect pest surveys periodically in enset production systems • Continue studying insect pest dynamics in relation to climate change
Sources of resistance of major insect pests	• Screen enset landraces for resistance to enset root mealybug • Indigenous knowledge study on pest control methods identified, documented, and tested	• Continue screening enset landraces for resistance to enset root mealy bug • Continue Indigenous knowledge study on pest control methods identified, documented, and tested	• Continue screening enset landraces for resistance to enset root mealy bug • Continue Indigenous knowledge study on pest control methods identified, documented, and tested
Integrated insect pest management	• Identify effective integrated insect pest management options Identify bio-pesticides and evaluate their efficacy on insect pests	• Continue identificaiton of effective integrated insect pest management options • Continue identification of bio-pesticides and evaluate their efficacy on insect pests	• Continue identificaiton of effective integrated insect pest management options • Continue identification of bio-pesticides and evaluate their efficacy on insect pests
Molecular studies on insect pest resistance	• Assess and identify genes for durable resistance using marker assistedselection(MAS)	• Continue assessing and identifying genes for durable resistance using marker assisted selections (MAS)	• Contiue assessing and identifying genes for durable resistance using marker assisted selections (MAS)

	• Conduct biotype analysis and race evolution mechanisms of major enset insect pests	• Continue conducting biotype analysis and race evolution mechanisms of major enset insect pests	• Continue conducting biotype analysis and race evolution mechanisms of major enset insect pests
Weed science			
Weed competitionin in enset production **Climate change on weed infestation** **Integrated weed management**	• Conduct periodical assessment of weed flora in enset production systems • Study the competition effects of grass and broad leaf weeds on enset • Quantify the effect of climate change on the intensity of weeds with their effects on enset production • Identify effective integrated weed management options • Screen effective chmicals for grass weed control in enset fields	• Continue conducting periodical assessment of weed flora in enset production Systems • Continue studying the competition effects of grass and broad leaf weeds on enset • Continue quantifying the effect of climate change on the intensity of weeds with their effects on enset production • Continue identifing effective integrated weed management options • Continue screening effective chmicals for grass weed control in enset fields	• Continue conducting periodical assessment of weed flora in enset production Systems • Continue studying the competition effects of grass and broad leaf weeds on enset • Continue quantifying the effect of climate change on the intensity of weeds with their effects on enset production • Continue identifing effective integrated weed management options • Continue screening effective chmicals for grass weed control for enset production
5. GIS and agro-meteorology			
GIS for operation of farm practices	• Develop GIS based agro-meteorology data for enset production in different production systems	• Continue developing GIS based agro-meteorology data for production of enset in different production systems	• Continue developing GIS based agro-meteorology data for production of enset in different production systems
Enset production suitability map	• Develop enset suitability map using GIS and agro-meteorology	• Continue refining enset production suitability map using GIS and agro meteorology	• Continue refining enset production suitability map using GIS and agro-meteorology
	• Develop enset production constraint map using crop modeling approach	• Continue developing suitability maps for enset production areas using crop modeling approach	• Finalize the suitability map of enset production areas
6. Technology multiplication and seed research			
Pre-basic seedling multiplication	• Determine and develop micro propagation protocols for enset seedling multiplication	• Continue development of micro propagation protocols for enset multiplication	• Continue development of micro propagation protocols for enset multiplication
	• Produce pre-basic seedling of released enset varieties in enough quantity and quality	• Continue producing pre-basic seedling of released enset varieties in enough quantity and quality	• Continue producing pre-basic seedling of released enset varieties in enough quantity and quality
	• Prepare enset seedling production manuals and guidelines	• Prepare laboratory manuals and protocols, seedling inspection procedures/manuals for	• Further continue preparation of manuals and protocols, seedling inspection

		quality control	procedures/manuals for quality control
Community based enset seed production	• Provide technical support to community based seedling producers for production of good quality and quantity of enset seedlings	• Continue providing technical support to community based seedling producers for production of good quality and quantity of enset seedlings	• Continue providing technical support to community based seedling producers for production of good quality and quantity of enset seedlings
7. Agricultural economics, extension and gender			
Enset farming systems	• Survey, diagnose and document the social, economic and cultural values of enset production and its constraints • Document indigenous knowledge on fermentation, food product and post-harvest techniques in different farming system.	• Continue survey, diagnose and document the social, economic and cultural values of enset production and its constraints • Continue documentation of indigenous knowledge on fermentation, food product and post-harvest techniques in different farming system.	• Continue survey, diagnose and document the social, economic and cultural values of enset production and its constraints • Continue documentation of indigenous knowledge on fermentation, food product and post-harvest techniques in different farming system.
Demonstration of enset technologies	• Establish enset information repository (web-based, different information and package delivery mechanisms) • Establish enset parks to provide a platform for other interventions • Participatory demonstration of available and new improved enset technologies in different agro-ecologies • Develop and distribute various communication material (leaf lets, fliers, production manuals) and use mass media to promote dissemination of enset technologies in local languages. • Organize trainings, field days and travelling workshops involving stakeholders to create awareness and popularization of enset technologies • Establish and effectively use innovation	• Strengthen enset information repository (web-based, different information and package delivery mechanisms) • Strengthen enset park to provide a platform for other interventions • Continue participatory demonstration of available and new enset technologies in different agro-ecologies • Continue developing and distributing various communication material (leaf lets, fliers, production manuals) and use mass media to promote dissemination of enset technologies in local languages. • Continue organizing trainings, field days and travelling workshops involving stakeholders to create awareness and popularization of enset technologies • Strengthen and promote innovation platforms for	• Establish enset information repository (web-based, different information and package delivery mechanisms) • Strengthen enset park to provide a platform for other interventions • Continue participatory demonstration of available and new enset technologies in different agro-ecologies • Continue developing and distributing various communication material (leaf lets, fliers, production manuals and mass media) to promote enset technologies in local languages. • Organize trainings, field days and travelling workshops involving stakeholders to create awareness and popularization of enset technologies • Continue strengthening and promoting innovation platforms for development and

	platforms for development and dissemination of enset technologies • Identify best ICT technologies for technology dissemination	development and dissemination of enset technologies	dissemination of enset technologies
Adoption and impact assessment	• Determine the extent of adoption of enset technologies and their impact	• Determine the extent of adoption of enset technologies and their impact	• Determine the extent of adoption of enset technologies and their impact
Value chain	• Conduct value chain study and identify constraints at different stages of the value chain • Establish stakeholder platform to promote enset research and development	• Strengthen value chain study and suggest efficient map • Strengthen stakeholders platform to promote enset research and development	• Strengthen value chain study and suggest efficient map • Strengthen stakeholders platform to promote enset research and development
Gender and youth in enset production	• Enhance the skills and knowledge of youth and women farmers on principles and methods of enset product preparation • Develop working modality to strengthen the participation of women and youth in enset research and promotion • Characterize and mainstream gender roles and perspectives in enset research and development	• Enhance the skills and knowledge of youth and women farmers on principles and methods of enset product preparation • Develop working modality to strengthen the participation of women and youth in enset research and promotion • Promote gender main streaming in enset research and development	• Enhance the skills and knowledge of youth and women farmers on principles and methods of enset product preparation • Develop working modality to strengthen the participation of women and youth in enset research and promotion • Promote gender main streaming in enset research and development
8. Agricultural mechanization			
Mechanization technologies	• Modify, design and develop enset processing mechanization/farm tools technologies suitable to different enset and affordable to smallholders. • Provide prototypes to enterprises for wide multiplication and distribution	• Modify, design, and develop enset processing mechanization/ farm tools technologies suitable to different enset and affordable to smallholders. • Provide prototypes to enterprises for wide multiplication and distribution	• Modify, design, and develop enset processing mechanization/ farm tools technologies suitable to different enset and affordable to smallholders. • Provide prototypes to enterprises for wide multiplication and distribution
9. Agricultural quality and post-harvest			
Nutritional and industrial potential of enset	• Assess nutritional quality of enset varieties and associated food products • Assess industrial potential of enset starch and fiber quality	• Assess nutritional quality of enset varieties and associated food products • Assess industrial potential of enset starch and fiber quality	• Continue assessing nutritional quality of enset varieties and associated food products • Assess industrial potential of enset starch and fiber quality

Enset Product development and Post-harvest handling	• Develop enset -based alternative and fortified food products • Develop recipes for enset-based alternative and fortified food product • Identify/determine post-harvest handling problems and losses • Identify/determine enset product (Kocho, bulla and fiber) management (handling and storage) technologies, • Establish standard specifications of some raw and finished products • Start controlled fermentation studies with selected culture strata	• Develop enset -based alternative and fortified food products • Develop recipes for enset-based alternative and fortified food product • Identify/determine post-harvest handling problems and losses • Continue development of enset product (Kocho, bulla and fiber) management technologies, • Establish standard specifications of some raw and finished products • Continue development and optimization of controlled fermentation studies with selected culture technologies	• Develop enset -based alternative and fortified food products • Develop recipes for enset-based alternative and fortified food product • Identify/determine post-harvest handling problems and losses • Enhance development of enset product (Kocho, bulla and fiber) management technologies, • Establish standard specifications of some raw and finished products • Enhance development and optimization of controlled fermentation studies with selected culture technologies
10. Capacity building			
Limmited manpower and high staff turnover	• Recruit qualified researchers for all disciplines • Device incentive mechanisms to retain staff • Create conducive working environment	• Maintain adequate level of qualified research staff	• Maintain adequate level of qualified research staff
Man power development	• Strengthen capacity and familiarize researchers with modern scientific tools through long and short term trainings and periodical mentorship • Organize short term and on-job trainings for support staff • Organize experience sharing and exchange visits	• Strengthen capacity and familiarize researchers with modern scientific tools through long and short term trainings and periodical mentorship • Organize short term and on-job trainings for support staff • Organize experience sharing and exchange visits	• Strengthen capacity and familiarize researchers with modern scientific tools through long and short term trainings and periodical mentorship • Organize short term and on-job trainings for support staff • Organize experience sharing and exchange visits

Facilities and infrastructure for Enset research	• Strengthen enset research capability in coordinating center (Areka) and other four (Holleta, Jimma, Hawassa, and Kulumsa) enset research centers • Provide adequate infrastructure for different research centers (e.g. offices, greenhouses, libraries/ICT, residential houses, social center, cold rooms, water supply, power supply, and land development and testing sites) • Provide adequate land and farm machinery for breeder and pre-basic seedling multiplication • Provide vehicles, office, field and laboratory equipment	• Strengthen enset research capability in coordinating center (Areka) and other four (Holleta, Jimma, Hawassa, and Kulumsa) enset research centers. • Provide adequate infrastructure for different research centres (e.g. offices, greenhouses, libraries/ICT, residential houses, social center, cold rooms, water supply, power supply, and land development and testing sites) • Provide adequate land and farm machinery for breeder and pre-basic seedling multiplication • Provide vehicles, office, field and laboratory equipment	• Strengthen enset research capability in coordinating center (Areka) and other four (Holleta, Jimma, Hawassa, and Kulumsa) enset research centers. • Provide adequate infrastructure for different research centers (e.g. offices, greenhouses, libraries/ICT, residential houses, social center, cold rooms, water supply, power supply, and land development and testing sites) • Provide adequate land and farm machinery for breeder and pre-basic seedling multiplication • Provide vehicles, office, field and laboratory equipment
Budget allocation and procurement	• Allocate adequate budget, • Improve the procurement process and release budget timely	• Allocate adequate budget • Improve the procurement process and release budget timely	• Allocate adequate budget, • Improve the procurement process and release budget timely
Crosscutting Themes			
Gender **Climate change** **Knowledge management**	• Consider gender equality and ensure that woman get their fair share of the benefits of research results; Since climate change is becoming a challenge, ensure that research programs would adequately address the challenge to increase resilience of vulnerable communities; and consider modern facilities of ICT are instrumental in knowledge and information transfer processes		

The Next Steps

In order for the strategy to be implemented in a coherent way, it is indispensable to develop a clear implementation plan. The strategic plan document should be viewed as a living constantly assessing the external and internal environment for changes regarding emerging opportunities or challenges, internal weaknesses and strengths as well as political, economic, socio-cultural, environmental, technological and legal challenges. The strategies and strategic plan should respond to the new external and internal environments. Therefore reviewing the strategic plan monitoring and evaluation, impact assessment and reassessment of the strategies and strategic plan should be done as required.

Annexes

Annex 1. Area, Production and Yield of Enset Crop for Meher Season 2011/12- 2015/16 E.C

Cropping year	Number of trees harvested	Production In Quintals			Total Production (Quintals)	Yield (Quintals/Tree)		
		Amicho	*Kocho*	*Bula*		*Amicho*	*Kocho*	*Bula*
2015/16	112522152	23821849.47	28329103.94	950414.35	53101367.76	0.21	0.25	0.01
2014/15	98002435	22929729.9	26219341.2	1022800.3	50171871.4	0.23	0.27	0.01
2013/14	130630473	31143132.27	34720355.36	1225934.66	67089422.00	0.24	0.27	0.01
2012/13	113999188	10936627.60	12985122.73	461,280.87	24383031.20	0.10	0.11	*
2011/12	312,171.98 hectares of land				7288686.96			

Potato Research Strategy

Introduction

Potato is among the few crops that the great majority of farming households in the cool highland areas of Ethiopia predominantly rely on as a source of food. It is probably the single commodity so universally relished in Ethiopian dishes invariably in the urban and rural settings all across the country. Its contribution to fill the food gap inexorably confronted by so many food-insecure areas and households during the lean periods of the year is particularly invaluable. In terms of area, potato with 0.3 million hectares accounts for 60% of the area under root crops and 29% under all horticultural crops; and production wise, with 3.66 million metric tons, it accounts for corresponding figures of 51 and 43 percent. It is also worth to note that with only 2.5% of the total area allotted to cereals, potato represents an equivalent of more than 14% of their production volume; which signifies the potential of potato in mitigating the ever widening gap between relentlessly rising population, and thus spiking food demand on hand and dwindling natural resource base and global climate change on the other.

Scientific research on potato began in 1973 by the then Alemaya College of Agriculture (now Haramaya University) in cooperation with the Institute of Agricultural Research (now EIAR) and the International Potato Center (CIP). However, a more-coordinated and multidisciplinary research with a much broader coverage of potato-growing regions of the country evolved following the transfer of the program to Holetta Agricultural Research Center in 1975. In 2005, the coordination was reassigned to Adet Agricultural Research Center. During the past one decade alone, the research registered remarkable results including the release of 16 disease-resistant, adaptable, and high-yielding varieties along with their packages of agronomic practices suitable for specific agro-ecologies; and disease management options.

Although a comprehensive potato research strategy was developed in the late 1990's during the tenure of EARO it was not implemented in its entirety due mainly to structural changes in the research system. In pursuit of delivering outputs matching national and sectoral economic drives; and aligned to the Government's development policy frameworks, EIAR is now impelled to develop a new research strategy for potato. The National Potato Research Program has prepared this long-term research strategy (2016-2030); which was drafted by building on the experiences and lessons gained from the previous strategy that was followed through, sparsely as it was, over the last fifteen years. This new research strategy has been developed by a multi-disciplinary team of researchers working on potato to: serve as the central document guiding their efforts for the next 15 years; and provide an all-inclusive framework for prioritizing and coordinating research activities towards the achievement of shared- vision and objectives.

The strategy is organized in six major chapters whereby this background section together with descriptions of the rationale, vision, mission, goal and objectives constitute the introductory chapter 1. Chapter 2 provides an overview of the importance of potato in the

Ethiopian agriculture; and food and nutrition security. Chapter 3 briefly discusses the situation analysis undertaken by assessing the internal environment as well as the external one involving all the key stakeholders to capture their reflections, concerns and desires. In chapter 4 are presented the critical issues that have been sifted out from the situation analysis and articulated as key challenges facing the program. Chapter 5 discusses the actual strategic interventions to be pursued under the various thematic areas of the research to tackle the critical issues identified. Chapter 6 provides key elements of follow up documents that need to be worked out in the next steps as they are prerequisites for effective implementation of the strategy.

Rationale

Lessons learned over the last several years indicate that judicious dissemination and application of proven technologies and inputs will bring about significant and positive changes in both the production and productivity of potato and the wellbeing of the producers. Cognizant of the available physiographic and climatic settings suitable for potato production coupled with conducive policy and regulatory frameworks put in place, potato can play a key role to: ensure food and nutrition security for millions of small-scale farming households; strengthen the opportunity for job creation and income generation; foster expansion of agro-industries, agri-business and import substitution; diversify the base for foreign earnings; and stabilize the macro-economy in general.

Therefore, the need for maximizing utilization of potential agro-climatic, physiographic and hydrologic conditions of the country to increase production, productivity and marketability of potato is a matter of urgency. In the present context though not only is wide the gap between what is available at research level and how much of that is being used by the farmer; but also are little the results attained thus far by the research system in comparison with the potential that could be realized from the crop. In order to create a condition where these divergent scenarios could converge and thus the commodity's potential could best be exploited, it is absolutely necessary to develop a well-defined and an all-inclusive research strategy representing and addressing the interests of all the key stakeholders involved in potato value chains. Such a strategy not only creates a stronger cohesion and partnership among stakeholders but also serves as a roadmap to: guide the research program planning and implementation in line with the objectives and targets of GTP-II and that of EIAR; track records of results and lessons; and mobilize resources from national and/or international sources. It is with this rationale that the National Potato Research Program (NPRP) - Team has developed this Research Strategy to achieve a common vision and objectives.

The NPRP -Team has a strong conviction that a thriving future for the commodity can be achieved only if it involves meaningful collaborations between farmers, input suppliers, exporters, actors in agribusiness and agro-industry, traders, technicians, scientists, and others engaged in the value chains. To this end, the research team has formulated a set of

principles and values that reflect its vision, mission, goal and objectives underpinning its commitments and desires as indicated below.

Vision

The vision of the National Potato Research Program (NPRP) is to be a competent research program availing technological innovations and knowledge that can significantly contribute to improved livelihoods and provision of competitive products for manufacturing industries and export market.

Mission

The mission of the NPRP is to conduct agro-ecology- and product- based research, generate, adapt and transfer technologies and knowledge that are acceptable by users for improving productivity, nutritional quality and sustainable development of agriculture, agribusiness and export market.

Goal

The goal of the NPRP is to contribute to the EIAR's role towards the achievement of the sectorial objectives of ensuring food security, sustainable delivering of raw materials for agro-industries and import substitution, expanding the bases for the country to gain foreign earnings from agricultural exports, and increasing livelihood resiliency and environmental sustainability while reducing vulnerability to climate change.

Objectives

The overall objective of the NPRP is to increase the production, productivity, quality and versatility of potato through multidisciplinary and participatory research approach leading to its increased share in the national economy and advancement. Specific objects of the program, among others, include the following:

- To generate and adapt potato technologies that can sustainably enhance productivity and quality to leverage its role in the food security, provide sustainable raw materials for manufacturing firms, import substitution and hard currency earnings ;
- To collect, characterize and conserve potato genetic resources for research use ;
- To generate and adapt potato technologies that can reduce child mortality and women health problems associated with malnutrition and thereby contribute to building a healthy and productive society and
- To generate technologies that provides competitive products for micro-processing businesses and creates jobs for rural and urban women and youth.

Importance of Potato

Although Ethiopia is neither the center of origin nor diversity for potato, it has free access to germplasm from the International Potato Center (CIP) which is the custodian of the biggest potato gene bank owing to its global mandate of furnishing needy-countries with genetic resources for public goods. In Ethiopia potato is grown in a wide range of agro-ecologies almost all through the year using the main- as well as belg- season rains, irrigation and residual moisture; thus allowing a continuous supply of fresh potato throughout. Agricultural areas in the northwest, central, south and south east represent the highest production of potato where more than 5 million smallholders farmers are engaged with a total area of around 0.3 million hectares producing about 3.7 million tons of potato annually. The national average productivity of potato has enormously increased from 5.7 MT/ha in the early 2000's to the present 12 plus MT/ha due partly to the coverage of improved varieties accounting for 25.2% of the total land cultivated under potato. Potato produces more food (dry matter) and protein per unit area; and more food per unit of water than any other major crop. A hectare of potato can feed 22 persons a year compared to rice of equivalent area feeding 19 persons. Potato yields approximately three times more energy than wheat, barley and oats. Hence, just 0.20 hectare of potato can cover the total annual energy demands of a family of two adults and three young children.

Over 65% of the potato produced in Ethiopia is meant for household consumption, mainly eaten boiled and for cooking stew. Since recently, however, other forms of utilization such as in making breads, cookies, Injera, complementary child foods, local drinks, and chips are evolving in towns; giving a new opportunity for agro-processing enterprises especially for the jobless youth. Nutritionally potato is an excellent source of carbohydrate, vitamins, minerals and the essential amino acid lysine which is used to fortify cereal products such as rice and pasta. It is a complete diet if consumed with milk for vitamin A supplement. With technologies useful for drying, potatoes can be turned into powder and thereby extend its shelf life to ensure sustainable food supply. Other branded-products could be developed for extraction of starches being used in textile, packaging, printing, and glue industries which at present are covering their needs exclusively imported products. While boarder trades in Djibouti, Somalia and Sudan represent a longstanding market-relationship, the potential of potato in earning foreign currency even beyond this traditional route is sizeable.

Situation Analysis

Two categories of forces and factors influencing the conception, formulation, action and implementation of the strategy were analyzed as external and internal factors. The external factors (influences that are outside the research system) represent both the interests of stakeholders that the research should serve and the potential role that they can play to complement or synergize the research. Specific situations or stakeholders'

interests that hold back research stride or the research falls short to positively respond to, represent the challenges (C); while those that create motivation for the research represent the opportunities (O). Therefore, the situation analysis of the external factors essentially examined Opportunities and Challenges (OC) presented from the existing Political /Policy /Legal, Economic, Educational, Socio-cultural, Technological/ Technical, and Environmental (PEST) perspectives of the factors. Almost all key stakeholders, notably the Ministries of: Agriculture and Natural Resources, Trade and Industries; exporters; private industries; farmers' unions; various relevant technical units of EIAR; the Regional Research Institutes and centers; and Higher Learning Institutions involved in Sub-tropical Fruit Crops research have taken part in the process.

Analysis of the internal situation (influences that are outside the research system) was made by scrupulously examining whether or not there is the capacity within the research system that can readily be deployed by the team to deliver outputs or promptly respond to stakeholders' quests or challenges. While the presence of such a capacity denotes the strength (S) of the team; the capacity which is required to deliver desirable outputs but falls short to exist represents the weakness (W). Therefore, analysis of the situation of internal factors examined Strengths and Weaknesses (SW) of the research team in terms of the existing resources (human, physical and fiscal); inter- and intra-disciplinary integrations, complementarities and synergies; availability of technologies, information and knowledge; and organization of internal system, and geographic coverage of the research program.

The results from the situation analysis were finally consolidated in a form of metrix whereby prevailing strengths, weaknesses, opportunities, and challenges (SWOC) were narrated with respect to their relevance to the various thematic areas that the research team is engaged in. From the situations narrated as such then were formulated the issues that the research system needs to address in the short-, medium-, and long- term plans. Experiences of other countries with respect to the level they have reached in research and development aspects of Sub-tropical fruit crops were also examined to set a benchmark for the strategy.

Strategic Issues

The major strategic thematic areas identified for the Potato Research Program include: Genetics and breeding; Agronomy and physiology; Technology multiplication and seed research; Crop protection; Irrigation water and nutrient management; Agricultural economics; Agricultural research extension and gender; Agricultural mechanization; Food science, postharvest management and value addition; GIS and Agro-meteorology; Capacity building; and Additional cross-cutting themes. Specific strategic issues pertaining to each thematic area are presented under Table 1.

Table .1 Strategic issues facing the National Potato Research Program and their relevance in the short-, medium- and long- terms

Thematic area	Strategic issue	Relevance in the		
		Short-term (1-5 years)	Medium-term (6-10 years)	Long-term (10-15 years)
Genetics and breeding	• Narrow genetic base and lack of diversity within the local genepool that can readily be deployed for improvement programs; • Lack of varieties resistant to major diseases; • Limited options of varietal choices for: extreme cool highlands, humid-midland areas with long-rain durations, areas with short rain/belg systems, drought-prone areas, and lowland areas with high day and night time temperatures; • Lack of varieties developed for irrigated production systems; • Lack of varieties suitable for processing purposes (French fries, crisps, salad, canning); • Lack of biofortified or nutritionally enhanced potato varieties and • No basic genetic information guiding the breeding work has been established for the widely grown local or improved varieties or advanced/elite materials in the breeding program.	x	x	x
Agronomy and physiology	• Inadequate packages of recommendations/technologies on cropping systems (mixed/inter-cropping, double cropping, crop rotation and cropping sequence) to fit potato in different production systems ; • Inadequate packages of agronomic practices (planting time, density, fertilizer type, rate, method and time of application, etc.) specific for different growing areas/production systems ; • Inadequate information on stress (drought, heat, frost, etc.) physiology ; • Lack of information on nutrient use efficiency of available potato germplasms to suit to farmers of different economic strata in terms of access to commercial fertilizers and • Lack of information on potential of potato to fit in systems pursuing conservation agriculture (CA) and climate-smart agriculture enhancing adaptation to and/or mitigation of climate change.	x	x	x
Technology multiplication and seed research	• Shortage of good-quality planting material of improved varieties and weak quality control system; • Inadequate information on potato seed science.	x	x	x
Crop protection	• Inadequate information on races of pathogens causing major diseases on potato (Phytophtera infestans, Ralstonia solanacearum and others) ;	x	x	x

	• Inadequate information on the biology, ecology, and population dynamics of important insect pests and vectors ; • Inadequate information on the epidemiology of major diseases affecting potato in different agro-ecologies and production systems ; • Inadequate IDM and IPM packages against diseases, insects and vectors ; • Inadequate disease management packages against bacterial wilt and • Absence of delineation of areas best suited for seed production or pest-risk zones to be precluded for seed-multiplication.			
Irrigation water and nutrient management	• Inadequate packages of recommendations on: macro-, micro-, inorganic and organic (compost, vermicompost, farmyard manure, green manure) fertilizers appropriate for different production (rain-fed, belg, moisture-stress, and irrigated) and processing (optimum nutrient concentrations in the tubers) scenarios ; • Inadequate information on water requirements and irrigation scheduling ; • Lack water-efficient irrigation technologies/systems appropriate for different agro-ecologies and soil types and • Lack of information on critical water depletion levels (crop coefficient-Kc) for different varieties and developmental stages.	x	x	x
Agricultural economics	• Inadequate information on characterization and diagnostics of potato-based farming systems, value chains and market efficiencies; • Inadequate feedback-information on technology adoption rate, diffusion intensity and impact and • Inadequate information on economics (technical and economic efficiencies) of potato production under smallholder grower's conditions.	x	x	x
Agricultural extension and gender	• Lack of gender-disaggregated information across the value chain of potato; • Inadequate knowledge and skill of farmers and agricultural experts on improved potato technologies ; • Inept and wasteful traditional methods used by key actors in the value chain to transport, market, process and consume potato and • Lack of well-consolidated and networked data base that can easily be accessed by users at all levels.	x	x	x
Agricultural mechanization	• Lack of agricultural machinery, implements and equipment for pre- and post- harvest operations (row planters, weeders, fertilizer-placers, cultivators, harvesters/lifters and graders) of potato under small-scale growers' conditions.	x	x	x

Food science, postharvest management and value addition	• Inadequate information on nutritional and physicochemical characteristics of improved varieties, elite materials and the available germplasm ; • Limited technologies of value-addition through semi-processing, full-processing, packaging and storing and • Heavy post-harvest loss and lack of management technologies to tackle the problem.	x	x	x
GIS and Agro-meteorology	• Lack of spatial suitability analyses, mapping, climate characterization and crop modeling.	x	x	x
Capacity building	Inadequate resources • Physical • Human • Finance	x	x	x
Additional crosscutting themes	• Climate change and knowledge management.	x	x	x

Note the mark "X" denotes that the issue is relevant and needs to be tackled

Research Themes and Strategic Interventions

Most of the research issues identified to be addressed by the potato research team are multi-institutional, multi-thematic, multidisciplinary, participatory, and need to be implemented in collaboration with farmers, extensionists and a wide range of other partners to be involved in the whole spectrum of the value chains. The research themes are built on the disciplinary as well as crosscutting themes briefly discussed hereunder. The strategic interventions proposed to tackle each of the issues identified for each theme, and need to be implemented during the next fifteen years on the: short-, medium- and long- term basis, are presented in Table 2 following the narrations of the disciplinary and cross-cutting thematic areas.

Research Themes

Genetics and breeding

In the years ahead, the potato sub-sector foresees a steady demand for varieties with higher and more stable yields and acceptable quality. To keep pace with this demand, much of the focus will be on developing new varieties that are high yielding, adapted to a variety of environments, and resilient in the face of multiple stresses such as climate change, emergence of new pests and diseases, and other biotic and abiotic factors. The strategy will generally seek to accelerate crop improvement by using both conventional and modern methods and technologies that make possible handling of large volumes of genetic material and select with greater precision. This will involve stronger integration of conventional plant breeding approaches with modern tools and methods of biotechnology.

Agronomy and physiology

Keeping the principle of eco-efficiency, the agronomy and crop physiology endeavor will focus towards developing improved crop management practices that open the way for optimal expression of genetic potential of varieties and enhancing the physiological and agronomic efficiency of the crop.

Technology multiplication and seed research

The core of research activities envisioned by the technology multiplication and seed research component of the strategy will be to: identify key problems associated with producing sufficient quantity and quality of initial material by generating basic information that would help to develop technologies addressing the challenges; adopt advanced tools of tissue culture for developing disease-free planting material of; identify and adopt good practices of technology multiplication for large-scale production of the crop; and devising an internal system whereby expeditious multiplication of high-quality planting material would be effected in order to meet ever growing demand.

Crop protection

To make crop production more eco-efficient is to achieve yield stability and reduce the

chances of crop failure due to diseases and other pests, whose dynamics are shifting as a result of climate change. To this end, the research will focus on both host plant resistance and biological control with greater emphasis to integrated approaches of controlling diseases, insect pests, weeds and vertebrate pests through Integrated Pest Management (IPM) systems.

Irrigation water and nutrient management

Development of water-efficient management practices including micro-irrigation, fertigation, irrigation scheduling, etc. constitute arears of intervention related to production of potato as it is best fitting for production under irrigation conditions.

Agricultural economics

Agricultural economics is among the core themes of research as it plays a vanguard role in linking the biological sphere of the research and the economic validity of the results when actually being implemented by the farmer or other targets in the recommendation domains. Furthermore, it has also a key role to play in addressing policy issues that are instrumental in developing and promoting efficient, functional and sustainable value chains of potato.

Agricultural extension and gender

The agricultural extension and gender component of the research brings in stakeholders together to formulate relevant research agenda as it does also take out promising research results to the demonstration and extension processes. Nevertheless the role the extension component plays in addressing the social aspects of the research, it is the main channel for the two-way flow of information between the research system on one hand and the end users of the research results on the other. Therefore, addressing issues related to socio-economic and research extension in the strategy is vital to attain the successes that the research team envisages. It will also be crucial to address issues related to gender equality and inclusiveness of the research process in general through this component.

Agricultural mechanization

The main challenges associated with agricultural machinery and post-harvest handling is the fact that producers in Ethiopia had little opportunity to employ small-scale farm implements, water pumps for irrigation, means of transportation, and storage structures that are appropriate for potato. Both pre- and post- harvest operations are done manually using age-old traditional methods. Losses in both quantities and qualities associated with these manual and dated practices are often appalling. It is therefore, imperative to consider this field of research in this research strategy.

Food science, postharvest management and value addition

Potato has a great deal of potential in the food industry. It is therefore, essential to work on chemical characterization and profiling of the available varietes and eventually the genepool for nutritional as well as industrial values. It is also critical to develop recommendations on post-harvest technologies that would improve shelf life of the produce. Establishing alternative ways of processing the produce in view of increasing their shelf life will also open up a new vista of value addition and product diversification and thus better market opportunities for producers and options of choices for consumers.

GIS and agro-meteorology

In formulating strategic interventions to be harnessed for achieving the objectives stipulated from the outset, it will be given due attention to GIS and agro-meteorology for better understanding of the dimensions of local climate and farming systems (physical climate, social, economic, farming systems, etc.) for targeting and developing the right technology for the right environment.

Capacity building

Two important issues were identified under this topic: the need for strengthening the capacity of the research team; and the stakeholders involved in the value chains in general need to have a strong, functional, influential and sustainable forum that will shape up the future of the research, production, processing, trade, and consumption of the commodity.

Crosscutting themes

Gender: The role of women in the agricultural system is critical as women contribute 70 percent of farm labour at harvesting and in post-harvest activities. But women farmers have only limited access to resources, services, land and credit. Unequal gender relations often make women more vulnerable to the effects of poverty, land degradation, and climate change. If the gender gap were eliminated, FAO asserts that total agricultural output would increase. Cognizant of this, the strategy upholds integration of gender concerns into research objectives, technology development, extension, and evaluation frameworks.

Climate change: In Ethiopia, climate change is already having an impact on the livelihoods of different communities in different corners of the country. Therefore, the research strategy will place due considerations to availing technologies that would help actors in the value chains to respond to climate change through adaptation and/or mitigation approaches.

Knowledge management (KM): Through KM interventions aided by new information technologies, it is possible to help improve smallholders' access to resources that help them improve their farm productivity and competitive ability. KM will also help to create research products in a more collaborative manner that makes them more suitable for diverse audiences. For this purpose, the research team will make results more readily available by spearheading formations of multi-stakeholder platforms that facilitate interaction and promote learning for change, mentoring, and networking.

Strategic Interventions

Table 2 Strategic interventions planned to address critical issues facing the National Potato Research Program in the short-, medium- and long- terms

Thematic areas	Strategic Interventions		
	Short term (5 years)	Medium term (10 years)	Long term (15 years)
5.2.1 Genetics and breeding			
Narrow genetic base; lack of varieties: with resistance to diseases, tolerance to extreme cool highland, adaptable to humid-midland with long-rainfall duration, areas with short rain/belg systems, drought-prone areas, lowland areas with high day and night time temperatures, suitable for irrigated-production systems, processing, and nutritionally enhanced/ biofortified; and lack of basic genetic information	• Broaden the genetic base by introducing germplasms from all possible external sources; • Generate variability through planned crossing between and/or among the local populations and introduced materials; • Introduce and adapt commercial varieties proved to be viable elsewhere for certain specific targets and objectives; • Adapt and optimize screening techniques for resistance breeding against important biotic stresses (fungi, bacteria, virus, insects) • Develop varieties: with resistance to diseases, tolerance to extreme cool highland; adaptable to humid-midland with long-rainfall duration, areas with short rain/belg systems, drought-prone areas, and lowland areas with high day and night time temperatures; and suitable for irrigated-production systems; • Evaluate the existing varieties, elite and germplasm materials for processing qualities and nutrient content; • Develop varieties biofortified for desirable contents of Fe and Zn and better nutritional	• Broaden the genetic base by introducing germplasms from all possible external sources; • Generate variability through planned crossing between and/or among the local populations and introduced materials; • Introduce and adapt new commercial varieties proved to be viable elsewhere for certain specific targets and objectives; • Adapt and optimize molecular techniques for resistance breeding against important biotic factors (fungi, bacteria, virus, insects); • Develop new varieties: with resistance to diseases, tolerance to extreme cool highland; adaptable to humid-midland with long-rainfall duration, areas with short rain/belg systems, drought-prone areas, and lowland areas with high day and night time temperatures; and suitable for irrigated-production systems; • Strengthen evaluation of the existing varieties, elite and germplasm materials for processing qualities and nutrient content; • Develop new varieties biofortified for	• Broaden the genetic base by introducing germplasms from all possible external sources; • Generate variability through planned crossing between and/or among the local populations and introduced materials; • Introduce and adapt new commercial varieties proved to be viable elsewhere for certain specific targets and objectives; • Strengthen and refine application of molecular techniques for resistance breeding against important biotic factors (fungi, bacteria, virus, insects); • Develop new varieties: with resistance to diseases, tolerance to extreme cool highland; adaptable to humid-midland with long-rainfall duration, areas with short rain/belg systems, drought-prone areas, and lowland areas with high day and night time temperatures; and suitable for irrigated-production systems; • Develop improved varieties with high levels of tolerance to abiotic stress factors

	quality ; • Study and establish such basic information as: genetic diversity, breeding values, adaptation range, etc. of the existing potato germplasm and • Prepare a catalogue of varieties registered to date under different institutions.	desirable contents of Fe and Zn and better nutritional quality ; • Refine the basic information on: genetic diversity, breeding values, adaptation range, etc. of the existing potato germplasm and • Update the catalogue of registered potato varieties.	using biotech tools (molecular characterization and in-vitro marker-assisted selection techniques); • Refine evaluation of the existing varieties, elite and germplasm materials for processing qualities and nutrient content; • Develop new varieties biofortified for desirable contents of Fe and Zn and better nutritional quality and • Update the catalogue of registered potato varieties.
5.2.2 Agronomy and physiology			
Inadequate packages of recommendations/ information on: cropping systems, area-specific agronomic practices, stress physiology, nutrient use efficiency, potential of potato to suit for conservation agriculture and climate-smart agriculture (	• Fine tune existing agronomic practices proved to be effective on both farmers' and research fields and update and resynthesize recommendation packages to fit to specific agro-ecologies, varieties, growing conditions ; • Develop technologies and packages of recommendations on potato-based cropping systems (mixed/inter-cropping, double cropping, crop rotation and cropping sequence) appropriate for rain- fed production conditions; • Develop packages of agronomic recommendations appropriate for specific purposes (seed *vs* ware potatoes), agro-ecologies and growing conditions (rain- fed *vs* irrigated); • Determine mechanisms of tolerance/resistance to abiotic/biotic stresses; • Determine morpho-physiological traits embedding tolerance to different factors of abiotic stress;	• Strengthen development of technologies and packages of recommendations on potato-based cropping systems appropriate for both rainfed and irrigated potato production; • Refine packages of agronomic recommendations appropriate for specific purposes (seed vs ware potatoes), agro-ecologies and growing conditions (rain -fed vs irrigated); • Strengthen research and refine results on mechanisms and morpho-physiological traits embedding tolerance to different factors of abiotic stress; including induced-stress conditions under growth chamber or in-vitro culture; • Strengthen profiling new varieties and germplasm with respect to nutrient-use efficiency; and develop options of varieties with gradients of nutrient-use efficiencies (along with appropriate agronomic practices)	• Strengthen development of resource-efficient (land, labor, capital, time) technologies and packages of recommendations on potato-based cropping systems appropriate for both rainfed and irrigated production conditions; • Refine packages of agronomic recommendations appropriate for specific purposes (seed vs ware potatoes), agro-ecologies and growing conditions (rain-fed vs irrigated); • Strengthen research and refine results on mechanisms and morpho-physiological traits embedding tolerance to different factors of abiotic stress using modern throughput techniques and technologies and • Strengthen profiling new varieties and germplasm with respect to nutrient-use

	• Profile the existing varieties and elite and germplasm materials with respect to their nutrient-use efficiency and • Generate information on potential of potato to fit in systems pursuing conservation agriculture and climate-smart agriculture enhancing adaptation to- and/or mitigation of- climate change; and develop recommendations to make use of the potential, if any.	to respond to farmers of different economic strata in terms of access to commercial fertilizers and • Refine packages of recommendations to make best use of potato for conservation and climate-smart agriculture.	efficiency; and develop options of varieties with gradients of nutrient-use efficiencies (along with appropriate agronomic practices) to respond to farmers of different economic strata in terms of access to commercial fertilizers.
5.2.3 Technology multiplication and seed research			
Shortage of good-quality planting material of improved varieties; weak quality-control system; and inadequate information on potato seed science	• Identify gaps, at institution, legislation or policy levels, that need to be promptly addressed to invigorate the potato seed system; and prepare and present to EIAR-top management a policy brief and/or recommendation ; • Multiply good-quality initial planting materials through conventional and/or unconventional techniques and promote their distribution; • Develop new techniques and methods of fast production of large quantities of good-quality early-generation seed ; • Determine: rate of degeneration of seed quality; and extent and causes of post-harvest seed losses at different seed production areas; • Develop options of management packages/technologies against: vectors; dormancy; and post-harvest seed losses and • Develop: the internal seed-quality control system; and packages of recommendations/ technologies for on-farm production and multiplication of planting material.	• Multiply good-quality initial planting materials through conventional and/or unconventional techniques and promote their distribution ; • Strengthen development of options of management packages/technologies against: vectors; dormancy; and post-harvest seed losses and • Strengthen: the internal seed-quality control system; and packages of recommendations/ technologies developed for on-farm production and multiplication of planting material.	• Multiply good-quality initial planting materials through conventional and/or unconventional techniques and promote their distribution ; • Refine options of management packages/technologies against: vectors; dormancy; and post-harvest seed losses and • Refine: the internal seed-quality control system; and packages of recommendations/ technologies developed for on-farm production and multiplication of planting material.

5.2.4 Crop protection			
Limited information on: races of major pathogens, biology, ecology, and population dynamics of major insect pests and vectors, and epidemiology of important diseases; inadequate IPM packages against diseases, insects and vectors; inadequate disease management packages against bacterial wilt; and absence of delineation of pest-risk zones for seed-multiplication	• Collect, determine and characterize races of the major pathogens using differentials; • Develop a baseline information on agro-ecological distributions of insect pests and vectors inflicting damages on potato; • Introduce and adapt IDM and IPM methods against major diseases, insect pests and vectors of potato ; • Undertake studies to understand: soil-health factors aggravating bacterial wilt; and dynamics of insect pests causing seed-health deterioration; and develop packages of recommendations/ technologies against these culprits and • Create awareness about integrated disease management through: developing and distributing simple handheld pocket guides; using multiple communication media; and advocacy for legislative support.	• Refine the race identification and characterization work using molecular and serological diagnostic techniques; • Undertake studies on host ranges of pathogens of potato and refine packages of IDM practices; • Generate information on: the biology, ecology, and population dynamics of major insect pests and vectors; • Generate information on: the ecology, epidemiology, race/biotypes, and dynamics of the major diseases; • Refine the IDM and IPM methods developed against major diseases, insect pests and vectors in light of information from the basic studies above; • Develop: methods for undertaking surveillance and monitoring on the emergence and dynamics of new and known pests and vectors; early-warning systems; and packages of management practices against the pests and vectors and • Strengthen awareness creation about integrated disease management through: developing and distributing simple handheld pocket guides; using multiple communication media; and advocacy for legislative support.	• Strengthen the race identification and characterization work using molecular and serological diagnostic techniques; • Refine information on: the biology, ecology, and population dynamics of major insect pests and vectors; • Refine information on: the ecology, epidemiology, race/biotypes, and dynamics of the major diseases; • Refine the IDM and IPM methods developed against major diseases, insect pests and vectors in light of new information from basic studies ; • Strengthen: methods for undertaking surveillance and monitoring on the emergence and dynamics of new and known pests and vectors; early-warning systems; and packages of management practices against the pests and vectors and • Strengthen awareness creation about integrated disease management through: developing and distributing simple handheld pocket guides; using multiple communication media; and advocacy for legislative support.
5.2.5 Irrigation water and nutrient management			
Inadequate packages of recommendations on: macro-, micro-, organic- and	• Fine tune the current fertilizer rates recommended for different agro-ecologies and production systems;	• Develop packages of recommendations on integrated soil fertility management practices appropriate for different agro-ecologies and	• Refine packages of recommendations on integrated soil fertility management practices appropriate for different agro-

inorganic- fertilizers appropriate for different production and processing scenarios; inadequate information on: water requirements, irrigation scheduling, and water-efficient irrigation systems appropriate for different agro-ecologies and soil types; and lack of information on critical water depletion levels for different varieties and developmental stages	• Determine new sources and rates of: organic and inorganic fertilizers to supply adequate amounts of both macro- and micro- nutrients required for production of high-quality potato in different agro-ecologies ; • Determine specific water and nutrient requirements and irrigation scheduling for different agro-ecologies and soil types; • Introduce and adapt water-efficient irrigation systems or technologies; • Initiate developing computer model-based irrigation regimes/ scheduling appropriate for different agro-ecologies and soil types and • Determine critical water depletion levels and crop-coefficients, Kc (which incorporate crop characteristics and averaged effects of evaporation from the soil) for different varieties and developmental stages.	production systems and quality targets; • Refine recommendations on new sources and rates of: organic and inorganic fertilizers to supply adequate amounts of both macro- and micro- nutrients required for production of high-quality potato in different agro-ecologies; • Strengthen and refine information on specific water and nutrient requirements and irrigation scheduling for different agro-ecologies and soil types; • Refine and develop water-efficient irrigation technologies appropriate for different production scenarios; • Develop, validate and map computer model-based irrigation regimes or scheduling appropriate for different agro-ecologies and soil types and • Update and expand the information on critical water depletion and crop coefficient.	ecologies and production systems and quality targets; • Refine recommendations on new sources and rates of: organic and inorganic fertilizers to supply adequate amounts of both macro- and micro- nutrients required for production of high-quality potato in different agro-ecologies; • Strengthen and refine information on specific water and nutrient requirements and irrigation scheduling for different agro-ecologies and soil types; • Refine and develop water-efficient irrigation technologies appropriate for different production scenarios; • Develop, validate and map computer model-based irrigation regimes/ scheduling appropriate for different agro-ecologies and soil types and • Update and expand the information on critical water depletion and crop coefficient.
5.2.6 Agricultural economics			
Inadequate information on: characterization and diagnosis of farming systems, value chains and market efficiencies; rate of technology adoption and diffusion and impact; and inadequate information on production economics	• Undertake characterization and diagnosis of farming systems incorporating potato ; • Conduct analysis of value-chains and determine market efficiencies in different potato-growing agro-ecologies ; • Develop systems of generating and communicating market information to different actors in the value chain ; • Undertake studies on: production economics	• Update the information on characterization and diagnosis of farming systems incorporating potato; • Conduct analysis of value-chains and determine market efficiencies in different potato-growing agro-ecologies ; • Update systems of generating and communicating market information to different actors in the value chain ;	• Update the information on characterization and diagnosis of farming systems incorporating potato ; • Conduct analysis of value-chains and determine market efficiencies in different potato-growing agro-ecologies ; • Update systems of generating and communicating market information to different actors in the value chain ;

	(cost-benefit), rate of adoption and impacts of potato technologies; • Generate information on policy and legislative issues, prepare policy brief and/or recommendation, discussion fora, and present to EIAR's top-management to be pursued at higher levels and • Establish stakeholders' platform and ensure participation of all actors in the value chain.	• Undertake studies on: production economics (cost-benefit), rate of adoption and impacts of potato technologies; • Generate information on policy and legislative issues, prepare policy brief and/or recommendation, discussion fora, and present to EIAR's top-management to be pursued at higher levels and • Strengthen stakeholders' platform and ensure participation of all actors in the value chain.	• Undertake studies on: production economics (cost-benefit), rate of adoption and impacts of potato technologies; • Generate information on policy and legislative issues, prepare policy brief and/or recommendation, discussion fora, and present to EIAR's top-management to be pursued at higher levels and • Strengthen stakeholders' platform and ensure participation of all actors in the value chain.
5.2.7 Agricultural extension and gender			
Lack of gender disaggregated information across the value chains; inadequate knowledge and skill on improved potato technologies across the production, processing, marketing and consumption continuum; and absence of easily accessible data base	• Characterize and mainstream gender roles and perspective in the processes of development and adoption of technologies; and production, marketing and utilization of potato; • Promote participatory technology development and promotion and • Create awareness and identify technology-cum-information dissemination and popularization methods enhancing production, processing and consumption of potato in both rural and urban areas (training, manuals, leaflets, etc., web-based digital repository, and international knowledge and technology banks).	• Characterize and mainstream gender roles and perspective in the processes of development and adoption of technologies; and production, marketing and utilization of potato; • Promote participatory technology development and promotion and • Create awareness and identify technology-cum-information dissemination and popularization methods enhancing production, processing and consumption of potato in both rural and urban areas (training, manuals, leaflets, etc., web-based digital repository, and international knowledge and technology banks).	• Characterize and mainstream gender roles and perspective in the processes of development and adoption of technologies; and production, marketing and utilization of potato; • Promote participatory technology development and promotion and • Create awareness and identify technology-cum-information dissemination and popularization methods enhancing production, processing and consumption of potato in both rural and urban areas (training, manuals, leaflets, etc., web-based digital repository, and international knowledge and technology banks).
5.2.8 Agricultural mechanization			
Lack of agricultural machinery, implements and equipment for pre- and post-	• Inventorize research-developed and locally available small-scale technologies, evaluate and promote those appropriate for pre- and post-	• Avail pre- and post-harvest mechanization technologies through adaptation to suit existing situations.	• Avail more advanced and appropriate pre- and post-harvest implements through adaptation to suit existing situations.

harvest operations	harvest management of potato(row planters, weeders, fertilizer-placers, cultivators, harvesters/lifters and graders); • Introduce and adapt agricultural mechanization technologies appropriate for small-scale farmers growing potato.		
5.2.9 Food science, postharvest management and value addition			
Inadequate information on nutritional and physicochemical characteristics of improved varieties, elite materials and the germplasm of potato; no technologies/ methods of semi- or full-processing, packaging and storing potato; and heavy post-harvest losses	• Generate information on physicochemical characteristics and processing-quality of improved varieties, elite materials and the available germplasm ; • Generate information on nutritional and anti-nutritional factors and profile of traditional potato-based staple foods ; • Develop methods and techniques of producing processed and value-added products of potato ; • Assess the causes and determine extent of postharvest losses across different production areas and market outlets and • Introduce and adapt post-harvest management technologies (harvesting, storage, handling, packaging, processing).	• Develop brand processing technologies (canned, fermented beverages, formulation of composite flour for weaning and therapeutic diets) for commercial purpose ; • Introduce and adapt small-scale semi-processing, processing and packaging equipment for food and non-food products.	• Introduce and adapt controlled atmosphere (temperature and humidity) storage techniques and technologies; • Develop brand processing technologies (canned, fermented beverages, formulation of composite flour for weaning and therapeutic diets) for commercial purpose and • Introduce and adapt small-scale semi-processing, processing and packaging equipment for food and non-food products.
5.2.10 GIS and Agro-meteorology			
Inadequate information on suitability mapping; and agro-climatology and crop modeling for potato production	• Conduct spatial suitability analyses and develop suitability map of potato across the various agro-ecologies; • Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall in meeting crop water requirements under rain-fed and irrigated systems;	• Refine and expand the suitability map; • Refine the modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall in meeting crop water requirements under rain-fed and irrigated systems and • Develop early warning and forecasting methods.	• Validate and refine suitability map; • Refine the modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall in meeting crop water requirements under rain-fed and irrigated systems and • Refine early warning and forecasting methods.

5.2.11 Capacity building			
Inadequate resources • Physical • Human • Finance	• Strengthen the number of research and technical staff through recruitment; • Improve technical cunning of the research staff through short- and long-term trainings tailored to upgrade research skills and qualifications; • Create favorable working environment (revising carrier structure, incentive mechanisms and reward external grant-winners) ; • Strengthen dexterity of researchers and technicians in application of specific topics through experience-sharing and study tours to places of excellence; • Furnish or Equip research centers with laboratories; offices; communication facilities; additional land for seed multiplication, trial and quarantine; and other research facilities; • Allocate sufficient budget for research and capacity building and improve efficiency of utilization and • Identify and organize research centers and sub-centers to assume the leading role to coordinate research on specific thematic area(s) of their competence.	• Strengthen the number, qualification and skill of the research and technical staff through recruitment, short- and long-term trainings and visits; • Create favorable working environment (revising carrier structure, incentive mechanisms and reward external grant-winners); • Strengthen the capacity of research centers with laboratories; offices; communication facilities; additional land for seed multiplication, trial and quarantine; and other research facilities; • Allocate sufficient budget for research and capacity building and improve efficiency of utilization and mobilize fund from external sources and • Strengthen research centers and sub-centers to assume the leading role to coordinate research on specific thematic area(s) of their competence.	• Strengthen the number, qualification and skill of the research and technical staff through recruitment, short- and long-term trainings and visits; • Create favorable working environment (revising carrier structure, incentive mechanisms and reward external grant-winners); • Strengthen the capacity of research centers with laboratories; offices; communication facilities; additional land for seed multiplication, trial and quarantine; and other research facilities; • Allocate sufficient budget for research and capacity building and improve efficiency of utilization and mobilize fund from external sources and • Strengthen research centers and sub-centers to assume the leading role to coordinate research on specific thematic area(s) of their competence.
5.2.12 crosscutting themes			
Gender	Organize gender disaggregated data for technology dissemination, adoption and impact of technologies; and in the course of technology demonstration, popularization, and training ensure that all female-headed households and at least 30% of beneficiaries to be women from male-headed households.		
Climate change	Develop research programs that would adequately address the challenge to increase resilience of vulnerable communities.		
Knowledge management	Consider modern facilities of ICT instrument in knowledge and information transfer and sharing processes.		

The Next Steps

Following the approval of the strategy by the top management of EIAR, it is essential to prepare the implementation plan, without which this strategy is not going to reach fruition. The implementation plan will be developed using a common Guideline adopted by the EIAR Planning, Monitoring and Evaluation Directo rate to provide guidance to research teams develop implementation plans. The implementation plan will thus come out as Volume II of the research strategy, which will serve as the blueprint to guide the National Potato Research for the next fifteen years (2016-2030). The major contents of the implementation plan will revolve, among others, around the following topics:

- Develop implementation plan;
- Develop monitoring and evaluation plan;
- Develop impact assessment plan and
- Develop reassessment plan for the strategy.

Root Crops Research Strategy

Introduction

The root crops (sweet potato, cassava, taro, yam and anchote) are most important crops in south, south west, south east and north western parts of Ethiopia where a great number of households predominantly rely on as a source of food. Research on the various root and tuber crops has been going on since the establishment of the Institute of Agricultural Research (IAR) in 1966 under horticultural crops research division at different research centers and in higher learning institutions in a fragmented manner. In 1997, the root crops research was reorganized at national level to constitute three projects (Enset; potato and sweetpotato; and other root crops) respectively being coordinated by Areka, Holetta and Hawassa Research Centers. Sweet potato is now part of the root crops research program. Although a comprehensive root crops research, strategy was developed in the late 1990s during the tenure of EARO it was not implemented in its entirety due mainly to structural changes in the research system. In pursuit of delivering outputs matching national and sectoral economic drives; and aligned to the Government's development policy frameworks, EIAR is now impelled to develop a new research strategy for these crops. Accordingly, the National Root Crops Research Program has prepared this long-term research strategy (2016-2030); which was drafted by building on the experiences and lessons gained from the previous strategy that was followed through, sparsely as it was, over the last fifteen years. This new research strategy has been developed by a multi-disciplinary team of researchers working on root crops to: serve as the central document guiding their efforts for the next 15 years; and provide an all-inclusive framework for prioritizing and coordinating research activities towards the achievement of shared- vision and objectives.

The strategy is organized in six major chapters whereby this background section together with descriptions of the rationale, vision, mission, goal and objectives constitute the introductory chapter 1. Chapter 2 provides an overview of the importance of root crops in the Ethiopian agriculture; and food and nutrition security. Chapter 3 briefly discusses the situation analysis undertaken by assessing the internal environment as well as the external one involving all the key stakeholders to capture their reflections, concerns and desires. In chapter 4 what ? are presented the critical issues that have been sifted out from the situation analysis and articulated as key challenges facing the program. Chapter 5 discusses the actual strategic interventions to be pursued under the various thematic areas of the research to tackle the critical issues identified. Chapter 6 provides key elements of follow up documents that need to be worked out in the next steps as they are prerequisites for effective implementation of the strategy.

Rationale

Lessons learned over the last several years indicate that judicious dissemination and application of proven technologies and inputs will bring about significant and positive changes in both the production and productivity of root crops and the wellbeing of the producers. Cognizant of the available physiographic and climatic settings suitable for root crops production coupled with conducive policy and regulatory frameworks put in place, the crops can play a key role to: ensure food and nutrition security for millions of small-scale farming households; strengthen the opportunity for job creation and income

generation; foster expansion of agro-industries, agri-business and import substitution; diversify the base for foreign earnings; and stabilize the macro-economy in general.

Therefore, the need for maximizing utilization of potential agro-climatic, physiographic and hydrologic conditions of the country to increase production, productivity and marketability of root crops is a matter of urgency. In the present context it is not only to widen the gap between what is available at research level and how much of that is being used by the farmer; but also are little the results attained thus far by the research system in comparison with the potential that could be realized from the crops. In order to create a condition where these divergent scenarios could converge and thus the commodities' potential could best be exploited, it is absolutely necessary to develop a well-defined and an all-inclusive research strategy representing and addressing the interests of all the key stakeholders involved in the value chains of root crops. Such a strategy creates a stronger cohesion and partnership among stakeholders and serves as a roadmap to: guide the research program planning and implementation in line with the objectives and targets of GTP-II and that of EIAR; records of accomplishment of results and lessons; and mobilize resources from national and/or international sources. It is with this rationale that the National Root Crops Research Program (NRCRP) - Team has developed this Research Strategy to achieve a common vision and objectives.

The NRCRP -Team has a strong conviction that a thriving future for the commodities can be achieved only if it involves meaningful collaborations between farmers, input suppliers, exporters, actors in agribusiness and agro-industry, traders, technicians, scientists, and others engaged in the value chains. To this end, the research team has formulated a set of principles and values that reflect its vision, mission, goal and objectives underpinning its commitments and desires as indicated below.

Vision

The vision of the National Root Crops Research Program (NRCRP) is to be a competent research program availing technological innovations and knowledge that can significantly contribute to improved livelihoods and provision of competitive products for manufacturing industries and export market

Mission

The mission of the NRCRP is to conduct agro-ecology- and product- based research, generate, adapt and transfer technologies and knowledge that are acceptable by users for improving productivity, nutritional quality and sustainable development of agriculture, agribusiness and export market

Goal

The goal of the NRCRP is to contribute to the EIAR's role towards the achievement of the sectorial objectives of ensuring food security, sustainable delivering of raw materials for agro-industries and import substitution, expanding the bases for the country to gain foreign earnings from agricultural exports, and (iv) increasing livelihood resiliency and environmental sustainability while reducing vulnerability to climate change

Objectives

The overall objective of the NRCRP is to increase the production, productivity, quality and versatility of root crops through multidisciplinary and participatory research approach leading to their increased share in the national economy and advancement. Specific objects of the program, among others, include the following:

- To generate and adapt technologies that can sustainably enhance productivity and quality of root crops to leverage their role in the food security, provide sustainable raw materials for manufacturing firms, import substitution and hard currency earnings;
- To collect, characterize and conserve the genetic resources of root crops for research use;
- To generate information on socio-economic aspects of root crops with regard to consumption, production and marketing and
- To generate technologies that provides competitive products for micro-processing businesses and creates jobs for rural and urban women and youth.

Importance of Root Crops

Production and utilization of root crops in Ethiopia dates back 3000 years ago with domestication of such indigenous root crops as "Ethiopian dinich", yam and Anchote; while production and utilization of introduced-root crops such as Irish and sweet potatoes and cassava elapsed only several hundred years; but are serving as staple food in a much wider areas of the country. Root crops are grown over a broad range of environments of mountain slopes (anchote and Ethiopian dinich*)* to zero meters above sea level (cassava). Sweetpotato is essentially a warm weather crop while cassava is both a tropical and subtropical drought tolerant crop. Taro is essentially a lowland crop partly because of its temperature sensitivity. Yam grows well in hot areas with temperatures between 25-30^{0}C and well distributed rainy days of 7-10 months. Anchote seems to have a wider ecological adaptation as it grows well in lowland, mid-land and highland areas. There are four major cropping seasons for root crops: the first and most frequently used is the Belg-season; the second is the Meher-season where farmers grow mainly for multiplication of planting materials; the third one is the residual system which is very common for the production of yam and sweetpotato where the residual moisture conserved during the main rainy season is utilized; and the forth system is by using irrigation mainly to produce planting materials and producing taro around water sources.

Root crops are rich sources of carbohydrate, starch, sugar, fiber and minerals such as calcium, magnesium, potassium, zinc and iron. They are also good sources of vitamins such as vitamins A (especially from orange-fleshed sweetpotato), B complex, C and E. Root crops cover around 1.5% of the area under crops and contribute for six percent of crop production in the country. As climate change is increasing becoming a threat to the production of cereal crops, the importance of root crops is expected to increase; as root crops are considered good emergency crops during failure of other crops due to climatic factors such as drought. They are the major source of food security for more than four million households representing ca. 22 million people in the south, south western and eastern parts of the country. Root crops can have a great potential to substitute import in

the textile, pharmaceutical, soft drink, beer and ethanol/alcohol industries as they can provide a wide array of products of industrial uses.

Situation Analysis

Two categories of forces and factors influencing the conception, formulation, action and implementation of the strategy were analyzed as external and internal factors. The external factors (influences that are outside the research system) represent both the interests of stakeholders that the research should serve and the potential role that they can play to complement or synergize the research. Specific situations or stakeholders' interests that hold back research stride or the research falls short to positively respond to, represent the challenges (C); while those that create motivation for the research represent the opportunities (O). Therefore, the situation analysis of the external factors essentially examined Opportunities and Challenges (OC) presented from the existing Political /Policy /Legal, Economic, Educational, Socio-cultural, Technological/ Technical, and Environmental (PEST) perspectives of the factors. Almost all key stakeholders, notably the Ministries of: Agriculture and Natural Resources, Trade and Industries; exporters; private industries; farmers' unions; various relevant technical units of EIAR; the Regional Research Institutes and centers; and Higher Learning Institutions involved in root crops research have taken part in the process.

Analysis of the internal situation (influences that are outside the research system) was made by scrupulously examining whether or not there is the capacity within the research system that can readily be deployed by the team to deliver outputs or promptly respond to stakeholders' quests or challenges. While the presence of such a capacity denotes the strength (S) of the team; the capacity which is required to deliver desirable outputs but falls short to exist represents the weakness (W). Therefore, analysis of the situation of internal factors examined Strengths and Weaknesses (SW) of the research team in terms of the existing resources (human, physical and fiscal); inter- and intra- disciplinary integrations, complementarities and synergies; availability of technologies, information and knowledge; and organization of internal system, and geographic coverage of the research program.

The results from the situation analysis were finally consolidated in a form of metrix whereby prevailing strengths, weaknesses, opportunities, and challenges (SWOC) were narrated with respect to their relevance to the various thematic areas that the research team is engaged in. From the situations narrated as such then were formulated the issues that the research system needs to address in the short-, medium-, and long- term plans. Experiences of other countries with respect to the level they have reached in research and development aspects of root crops were also examined to set a benchmark for the strategy.

Strategic Issues

The major strategic thematic areas identified for the Root Crops Research Program include: Genetics and breeding; Crop protection; Agronomy and physiology; Irrigation water and nutrient management; GIS and Agro-meteorology; Technology multiplication and seed research; Agricultural economics; Agricultural research extension and gender; Agricultural mechanization; Food science, postharvest management and value addition; Capacity building; and Additional cross-cutting themes. Specific strategic issues pertaining to each thematic area are presented under Table 1.

Table .1 Strategic issues facing the National Root Crops Research Program and their relevance in the short-, medium- and long- terms

Thematic area	Strategic issue	Relevance in the		
		Short-term (1-5 years)	Medium-term (6-10 years)	Long-term (10-15 years)
Genetics and breeding	• Lack of early-maturing varieties; • Limited number of varieties that meet farmers' preferences in terms of quality traits such as dry matter, β-carotene and hydrogen cyanide (HCN) contents; • Limited number of varieties suitable for stress areas and marginal environments • Lack of varieties to be used as raw material for targeted purposes such as processing of starch, flour, chips, • Lack of dual-purpose varieties of root crops that can also be used as leafy vegetables; • Inadequate utilization of the potential use of modern biotechnological tools in breeding and • Inadequate engagement in breeding for improving nutritional quality of root crops (e.g. micronutrients).	x	x	x
Crop protection	Pathology • Limited periodic survey and surveillance on diseases of root crops; • Inadequate results on identification of sources of resistance to diseases and specific races/pathotypes; • Inadequate utilization of the potential use of modern biotechnological tools to identify sources of disease resistance; • Inadequate options of integrated disease management (IDM) practices suitable for different agro-ecologies and production systems and • Inadequate utilization of the potential use of GIS for disease mapping Entomology • Limited periodic survey and surveillance on existing and newly emerging insect pests of root and tuber crops; • Inadequate results on identification of sources of resistance to major insect pests of root crops; • Inadequate options of integrated pest management (IPM) practices suitable for different agro-ecologies and production systems; • Inadequate information on efficacy of bio-pesticides used against insect pests of root crops; • Lack of information on storage pests and their management options • Inadequate research on botanicals for the control of major insect pests of root crops;	x	x	x

	Weed Science • Limited periodic survey and surveillance on weed flora incidence and abundance; • Inadequate information on biology of weeds and their competition effects on root crops; • Inadequate information on the effects of climate change on weed dynamics and associated losses of root crops; • Inadequate options of integrated weed management (IWM) practices suitable for different agro-ecologies and production systems and • Inadequate utilization of the potential use of GIS for mapping distributions of weeds			
Agronomy and physiology	• Lack of packages of agronomic recommendations specific to agro-ecologies and/or production systems; • Inadequate agronomic recommendations appropriate for marginal environments; • Lack of packages of agronomic recommendations on integrated nutrient management practices for different agro-ecologies; • Little/no information on micro-nutrient requirement and utilization; • Inadequate information on appropriate rate of organic fertilizers (compost, manures) and • Limited information on crop physiology and modeling	x	x	x
Irrigation water and nutrient management	• Inadequate packages of recommendations on crop-water requirements and irrigation scheduling appropriate for producing root crops under small- and large- scale irrigation conditions • Lack of data base on the available and/or potential irrigation schemes as to their suitability for production of root crops;	x	x	x
GIS and Agro-meteorology	• Lack of GIS-based information and knowledge applicable for timely operation of farm practices optimizing use of scarce resources; • Inadequate information on suitability map of the different agro-ecologies for root crops production	x	x	x
Technology multiplication and seed research	• Lack of focus/interest by seed enterprises to engage in multiplication of planting material of root crops; • Shortage of planting material of early-generations (pre-basic and basic seed levels) of root crops with sufficient quantity and quality; • Limited technical support given to farmers, seed-grower cooperatives and private seed producers; • Lack of recommendations on storage systems that enable to maintain quality of planting material; • Lack of awareness about/ emphasis to the importance of using planting material that are strictly free from diseases and pests	x	x	x

Agricultural economics	• Limited information on characterization and diagnostics of farming systems in different agro-ecologies involving root crops; • Limited information on adoption and impact of technologies on root crops; • Inadequate information on value chains, marketing and market efficiencies of root crops	x	x	x
Agricultural extension and gender	• Inadequate course of action of demonstration and popularization hastening the uptake of improved technologies as well as forward- and backward- flow of information/feedback; • Limited stance of gender mainstreaming in the processes of development and adoption of technologies; and production, marketing and utilization of root crops	x	x	x
Agricultural mechanization	• Lack of mechanization technologies for pre- and post-harvest operations (such as row planters, harvesters and storage facilities) appropriate for smallholder farmers; • Limited supply of prototypes of even the little number and type of pre- and post- harvest machineries at hand for their wider multiplication and distribution; • Inadequate information on efficiencies of pre- and post- harvest machineries at hand; • Lack of participatory processes involving farmers and experts as well in the course of developing and evaluating farm equipment before the technologies are multiplied and distributed	x	x	x
Food science, postharvest management and value addition	• Lack of recommendations on storage methods increasing the shelf life of products of root crops; • Inadequate information on nutritional qualities and anti-nutritional contents of root crops; including compositions of macro and micro nutrients; • Lack of technologies/methods for fortification and/or root crops-based alternative food products	x	x	x
Capacity building	Inadequate resources • Physical • Human • Finance	x	x	x
Additional crosscutting themes	• Climate change and knowledge management	x	x	x

Note the mark "X" denotes that the issue is relevant and needs to be tackled

Research Themes and Strategic Interventions

Most of the research issues identified to be addressed by the root crops research team are multi-institutional, multi-thematic, multidisciplinary, participatory, and need to be implemented in collaboration with farmers, extensionists and a wide range of other partners to be involved in the whole spectrum of the value chains. The research themes are built on the disciplinary as well as crosscutting themes briefly discussed hereunder. The strategic interventions proposed to tackle each of the issues identified for each theme, and need to be implemented during the next fifteen years on the: short-, medium- and long- term basis, are presented in Table 2 following the narrations of the disciplinary and cross-cutting thematic areas.

Research Themes

Genetics and breeding

In the years ahead, the root crops sub-sector foresees a steady demand for varieties with higher and more stable yields and acceptable quality. To keep pace with this demand, much of the focus will be on developing new varieties that are high yielding, adapted to a variety of environments, and resilient in the face of multiple stresses such as climate change, emergence of new pests and diseases, and other biotic and abiotic factors. The strategy will generally seek to accelerate crop improvement by using both conventional and modern methods and technologies that make possible handling of large volumes of genetic material and select with greater precision. This will involve stronger integration of conventional plant breeding approaches with modern tools and methods of biotechnology.

Crop protection

To make crop production more eco-efficient is to achieve yield stability and reduce the chances of crop failure due to diseases and other pests, whose dynamics are shifting as a result of climate change. To this end, the research will focus on both host plant resistance and biological control with greater emphasis to integrated approaches of controlling diseases, insect pests, weeds and vertebrate pests through Integrated Pest Management (IPM) systems.

Agronomy and physiology

Keeping the principle of eco-efficiency, the agronomy and crop physiology endeavor will focus towards developing improved crop management practices specifically tailored for particular growing conditions and thus open the way for optimal expression of genetic potential of varieties and enhancing the physiological and agronomic efficiencies of the crops.

Irrigation water and nutrient management

Development of water-efficient management practices including micro-irrigation, fertigation; irrigation scheduling, etc. constitute arrears of intervention related to production of root crops as they are best fitting for production under irrigation conditions.

GIS and agro-meteorology

In formulating strategic interventions to be harnessed for achieving the objectives stipulated from the outset, it will be given due attention to GIS and agro-meteorology for better understanding of the dimensions of local climate and farming systems (physical climate, social, economic, farming systems, etc.) for targeting and developing the right technology for the right environment.

Technology multiplication and seed research

The core of research activities envisioned by the technology multiplication and seed research component of the strategy will be to: identify key problems associated with producing sufficient quantity and quality of initial material by generating basic information that would help to develop technologies addressing the challenges; adopt advanced tools for developing disease-free planting material; identify and adopt good practices of technology multiplication for large-scale production; and devise an internal system whereby expeditious multiplication of high-quality planting material would be effected in order to meet ever growing demands.

Agricultural economics

Agricultural economics is among the core themes of research as it plays a vanguard role in linking the biological sphere of the research and the economic validity of the results when actually being implemented by the farmer or other targets in the recommendation domains. Furthermore, it has also a key role to play in addressing policy issues that are instrumental in developing and promoting efficient, functional and sustainable value chains of root crops.

Agricultural extension and gender

The agricultural extension and gender component of the research brings in stakeholders together to formulate relevant research agenda as it does also take out promising research results to the demonstration and extension processes. Notwithstanding the role the extension component plays in addressing the social aspects of the research, it is the main channel for the two-way flow of information between the research system on one hand and the end users of the research results on the other. Therefore, addressing issues related to socio-economic and research extension in the strategy is vital to attain the successes that the research team envisages. It will also be crucial to address issues related to gender equality and inclusiveness of the research process in general through this component.

Agricultural mechanization

The main challenges associated with agricultural machinery and post-harvest handling is the fact that producers in Ethiopia had little opportunity to employ small-scale farm implements, water pumps for irrigation, means of transportation, and storage structures that are appropriate for root crops. Both pre- and post- harvest operations are done manually using age-old traditional methods. Losses in both quantities and qualities associated with these manual and dated practices are often appalling. It is therefore, imperative to consider this field of research in this research strategy.

Food science, postharvest management and value addition

As root crops have a great deal of potential in the food industry, it is essential to work on chemical characterization and profiling of the available varietes and eventually the genepool for nutritional as well as industrial values. It is also critical to develop recommendations on post-harvest technologies that would improve shelf life of the produce. Establishing alternative ways of processing the produce in view of increasing their shelf life will also open up a new vista of value addition and product diversification and thus better market opportunities for producers and options of choices for consumers.

Capacity building

Two important issues were identified under this topic: the need for strengthening the capacity of the research team; and the stakeholders involved in the value chains in general need to have a strong, functional, influential and sustainable forum that will shape up the future of the research, production, processing, trade, and consumption of the commodities.

Crosscutting themes

Gender: The role of women in the agricultural system is critical as women contribute 70 percent of farm labour at harvesting and in post-harvest activities. But women farmers have only limited access to resources, services, land and credit. Unequal gender relations often make women more vulnerable to the effects of poverty, land degradation, and climate change. If the gender gap were eliminated, FAO asserts that total agricultural output would increase. Cognizant of this, the strategy upholds integration of gender concerns into research objectives, technology development, extension, and evaluation frameworks.

Climate change: In Ethiopia, climate change is already having an impact on the livelihoods of different communities in different corners of the country. Therefore, the research strategy will place due considerations to availing technologies that would help actors in the value chains to respond to climate change through adaptation and/or mitigation approaches.

Knowledge management (KM): Through KM interventions aided by new information technologies, it is possible to help improve smallholders' access to resources that help them improve their farm productivity and competitive ability. KM will also help to create research products in a more collaborative manner that makes them more suitable for diverse audiences. For this purpose, the research team will make results more readily available by spearheading formations of multi-stakeholder platforms that facilitate interaction and promote learning for change, mentoring, and networking.

Strategic Interventions

Table 2 Strategic interventions planned to address critical issues facing the National Root Crops Research Program in the short-, medium- and long- terms

Thematic areas	Strategic Interventions		
	Short term (5 years)	**Medium term (10 years)**	**Long term (15 years)**
5.2.1 Genetics and breeding			
Lack of varieties with: early-maturity, quality traits of farmers' preferences, adaptability to stress environments, suitability as raw material for processing and dual-use for root and leaf; inadequate use of: modern biotechnological tools and breeding for improving nutritional quality	• Screen local collections and identify early-maturing genotypes to use them for: direct development of varieties or gene sources to transfer earliness onto established varieties, elite materials or other breeding entries to be developed into new varieties; • Introduce, adapt and register early-maturing varieties suitable for the local growing conditions; • Identify, characterize, delineate, map and document major environments considered to be marginal for production of root crops; • Screen local collections and identify accessions that can be used to develop varieties suitable for marginal environments; • Introduce, adapt and register varieties suitable for marginal environments; • Screen local collections and identify genotypes with desirable characteristics of starch, suitability for leaf consumption and other traits; • Introduce, adapt and register varieties suitable for industrial processing and leaf consumption; • Undertake chemical characterization and	• Broaden the genetic bases of sweetpotato, cassava and yam through planned and extensive hybridization programs targeted for: earliness, adaptability to marginal environments, high starch content and transfer of other desirable traits; • Broaden the genetic bases of root crops through planned and extensive hybridization programs targeted for high- dry matter, β-carotene, Fe and Zn, and low-HCN contents; • Strengthen the source of genetic variability for: earliness, adaptation to marginal environments, industrial processing and dual-purposes of root and leaf consumption through rigorous and effective screening and selection of both local and introduced germplasm material ; • Strengthen the source of genetic variability for high- dry matter, β-carotene, Fe and Zn, and low-HCN contents through rigorous and effective screening and selection of both local and introduced germplasm material; • Develop root crop varieties which in addition to high-yielding are tailored for: earliness, adaptation to marginal environments, industrial processing and dual-purposes of root and leaf consumption;	• Broaden the genetic bases of sweetpotato, cassava and yam through planned and extensive hybridization programs targeted for: earliness, adaptability to marginal environments, high starch content and transfer of other desirable traits; • Broaden the genetic bases of root crops through planned and extensive hybridization programs targeted for high- dry matter, β-carotene, Fe and Zn, and low-HCN contents; • Strengthen the source of genetic variability for: earliness, adaptation to marginal environments, industrial processing and dual-purposes of root and leaf consumption through rigorous and effective screening and selection of both local and introduced germplasm material ; • Strengthen the source of genetic variability for high- dry matter, β-carotene, Fe and Zn, and low-HCN contents through rigorous

	profiling of released varieties, and elite or germplasm materials of root crops using modern biotechnological tools; • Introduce, adapt and register varieties with high- dry matter and β-carotene and low-HCN contents; • Initiate screening of local germplasm material for high- dry matter, β-carotene, Fe and Zn, and low-HCN contents and • Maintain and produce, at suitable research centers/sites, sufficient quantity and quality of breeder seeds of released varieties of root crops.	• Develop root crop varieties with high- dry matter, β-carotene, Fe and Zn, and low-HCN contents; • Strengthen chemical characterization and profiling of released varieties, and elite or germplasm materials of root crops using modern biotechnological tools; • Carry out studies on genotyping and mapping of resistances of selected root crops to major disease and insect pests and • Maintain and produce, at suitable research centers/sites, sufficient quantity and quality of breeder seeds of released varieties of root crops.	and effective screening and selection of both local and introduced germplasm material; • Develop root crop varieties which in addition to high-yielding are tailored for: earliness, adaptation to marginal environments, industrial processing and dual-purposes of root and leaf consumption; • Develop root crop varieties with high- dry matter, β-carotene, Fe and Zn, and low-HCN contents; • Strengthen chemical characterization and profiling of released varieties, and elite or germplasm materials of root crops using modern biotechnological tools; • Strengthen and refine studies on genotyping and mapping of resistances of root crops to major disease and insect pests and • Maintain and produce, at suitable research centers/sites, sufficient quantity and quality of breeder seeds of released varieties of root crops.
5.2.2 Crop protection			
• Pathology • Limited survey and surveillance on diseases; inadequate: sources of resistance; use of biotechnological tools	Pathology • Undertake periodic disease surveys sufficiently covering the major areas and seasons where/in which root crops are produced ; • Conduct postharvest disease surveys and	Pathology • Undertake periodic disease surveys sufficiently covering the major areas and seasons where/in which root crops are produced and establish dynamic changes encountered over time;	Pathology • Undertake periodic disease surveys sufficiently covering the major areas and seasons where/in which root crops are produced and establish dynamic

to identify sources of resistance; options of IDM practices; and use of GIS for disease mapping; • • Entomology • Limited survey and surveillance on existing and newly emerging insect pests; inadequate: sources of resistance; options of IPM practices; and information on efficacy of bio-pesticides, storage pests and their management, and botanicals and • • Weed Science • Limited survey and surveillance on weed flora; inadequate information on: biology and competition effects of weeds, effects of climate change on weed dynamics and associated losses, options of IWM practices, and use of GIS for mapping weed distributions .	determine the causes and extent of quantitative and qualitative losses of root crops across different production areas and seasons; • Identify virulent races of pathogens causing major diseases in root crops ; • Identify genetic sources of resistance, against major diseases, to be used for: direct development of varieties or transfer of resistance-genes onto established varieties and elite or other materials in the breeding program; • Undertake characterization and profiling of released varieties, and elite or germplasm materials of root crops with respect to their resistance to major diseases using modern biotechnological tools and • Develop options of effective integrated disease management (IDM) practices appropriate for different agro-ecologies and production systems. Entomology • Undertake periodic surveys on insect pests sufficiently covering the major areas and seasons where/in which root crops are produced; • Conduct postharvest surveys on insect pests, identify major storage pests and determine the causes and extent of quantitative and qualitative postharvest losses of root crops across different production areas and seasons ; • Undertake extensive screening of landraces of root crops and identify genotypes with resistance against such	• Conduct postharvest disease surveys and determine the causes and extent of quantitative and qualitative losses of root crops across different production areas and seasons; and establish dynamic changes encountered over time; • Strengthen identification of virulent races of pathogens causing major diseases in root crops ; • Develop varieties in which resistance genes from identified sources were introgressed; and also strengthen identification of new sources of resistance ; • Strengthen characterization and profiling of released varieties, and elite or germplasm materials of root crops with respect to their resistance to major diseases using modern biotechnological tools and • Develop options of effective integrated disease management (IDM) practices appropriate for different agro-ecologies and production systems. Entomology • Undertake periodic surveys on insect pests sufficiently covering the major areas and seasons where/in which root crops are produced; and establish dynamic changes encountered over time; • Conduct postharvest surveys on insect pests, identify major storage pests and determine the causes and extent of quantitative and qualitative postharvest losses of root crops across different production areas and seasons; Undertake periodic surveys on insect pests sufficiently covering the major areas and	changes encountered over time; • Conduct postharvest disease surveys and determine the causes and extent of quantitative and qualitative losses of root crops across different production areas and seasons; and establish dynamic changes encountered over time; • Refine identification of virulent races of pathogens causing major diseases in root crops ; • Develop new varieties in which resistance genes from identified sources were introgressed; and also strengthen identification of new sources of resistance; • Strengthen and refine characterization and profiling of released varieties, and elite or germplasm materials of root crops with respect to their resistance to major diseases using modern biotechnological tools and • Develop options of effective integrated disease management (IDM) practices appropriate for different agro-ecologies and production systems. Entomology • Undertake periodic surveys on insect pests sufficiently covering the major areas and seasons where/in which root crops are produced; and establish dynamic

	major pests as sweetpotato- weevil and butterfly; cassava-scale insect; and others; • Introduce and evaluate clones from exotic sources for resistance to major insect pests of root crops; • Develop options of effective integrated pest management (IPM) practices appropriate for different agro-ecologies and production systems and • Establish facts on identification and efficacies of: biological enemies, bio-pesticides, and botanicals; and develop packages of recommendations to control insect pests using these options. Weed Science • Establish basic knowledge and information on identity, abundance, biology, ecology and dynamics of the weed flora in root crops-growing agro-ecologies and production systems; • Establish competition effects of grass and broad-leaf weeds on quantitative as well as qualitative losses of root crops across agro-ecologies and production systems; • Develop options of effective integrated weed management (IWM) practices appropriate for different agro-ecologies and production systems; • Undertake studies on the impact of climate change on weed dynamics and its implicit effects on root crops production and • Establish GIS-based mapping of the identity and abundance of the weed flora	seasons where/in which root crops are produced; and establish dynamic changes encountered over time ; • Undertake extensive screening of new landraces of root crops and identify genotypes with resistance against such major pests as sweetpotato- weevil and butterfly; cassava-scale insect; and others ; • Introduce and evaluate new clones from exotic sources for resistance to major insect pests of root crops; • Develop options of effective integrated pest management (IPM) practices appropriate for different agro-ecologies and production systems; • Establish facts on identification and efficacies of new: biological enemies, bio-pesticides, and botanicals; and develop packages of recommendations to control insect pests using these options Weed Science; • Strengthen the basic knowledge and information on identity, abundance, biology, ecology and dynamics of the weed flora in root crops-growing agro-ecologies and production systems ; • Strengthen the information on competition effects of grass and broad-leaf weeds on quantitative as well as qualitative losses of root crops across agro-ecologies and production systems; • Develop options of effective integrated weed management (IWM) practices appropriate for different agro-ecologies and production systems ;	changes encountered over time; • Conduct postharvest surveys on insect pests, identify major storage pests and determine the causes and extent of quantitative and qualitative postharvest losses of root crops across different production areas and seasons; Undertake periodic surveys on insect pests sufficiently covering the major areas and seasons where/in which root crops are produced; and establish dynamic changes encountered over time ; • Undertake extensive screening of new landraces of root crops and identify genotypes with resistance against such major pests as sweetpotato- weevil and butterfly; cassava-scale insect; and others ; • Introduce and evaluate new clones from exotic sources for resistance to major insect pests of root crops; • Develop options of effective integrated pest management (IPM) practices appropriate for different agro-ecologies and production systems ; • Establish facts on identification and efficacies of new: biological enemies, bio-pesticides, and botanicals; and develop packages of recommendations to control insect pests using these options. Weed Science

	in root crops-growing agro-ecologies and production systems.	• Strengthen studies on the impact of climate change on weed dynamics and its implicit effects on root crops production and • Refine the information on GIS-based mapping of the identity and abundance of the weed flora in root crops-growing agro-ecologies and production systems.	• Strengthen and refine the basic knowledge and information on identity, abundance, biology, ecology and dynamics of the weed flora in root crops-growing agro-ecologies and production systems ; • Refine the information on competition effects of grass and broad-leaf weeds on quantitative as well as qualitative losses of root crops across agro-ecologies and production systems; • Develop options of effective integrated weed management (IWM) practices appropriate for different agro-ecologies and production systems and • Refine the information on the impact of climate change on weed dynamics and its implicit effects on root crops production; and on GIS-based mapping of the identity and abundance of the weed flora in root crops-growing agro-ecologies and production systems.
5.2.3 Agronomy and physiology			
Lack of specific agronomic recommendations for: different agro-ecologies and systems, marginal environments, and integrated nutrient	• Develop appropriate packages of agronomic recommendations (planting time and density/spacing, rate of application of organic and inorganic fertilizers, etc.) specific to agro-ecologies and production systems ; • Develop packages of agronomic recommendations appropriate for acidic	• Fine tune packages of agronomic recommendations (planting time and density/spacing, rate of application of organic and inorganic fertilizers, etc.) specific to agro-ecologies and production systems; • Strengthen and update packages of agronomic recommendations appropriate for acidic soils, and low-moisture and waterlogged areas;	• Fine tune packages of agronomic recommendations (planting time and density/spacing, rate of application of organic and inorganic fertilizers, etc.) specific to agro-ecologies and production systems; • Strengthen and update packages

management; little/no information on: micronutrient utilization and crop physiology and modeling.	soils, and low-moisture and waterlogged areas; • Develop packages of recommendations on integrated nutrient management practices including micronutrients appropriate for root crops; • Undertake systematic studies on crop physiology and generate information useful to enhance: plant efficiencies of water use, photosynthesis, and nutrient use; and crop growth and development and • Develop crop-modeling tools that can be employed to forecast short- and long-term local climate patterns in, and determine effects of climate change on root crops production systems.	• Refine packages of recommendations on integrated nutrient management practices including micronutrients appropriate for root crops; • Undertake systematic studies on crop physiology and generate information useful to enhance: plant efficiencies of water use, photosynthesis, and nutrient use; and crop growth and development and • Refine crop modeling tools that can be employed to forecast short- and long- term local climate patterns in, and also determine effects of climate change on root crops production systems.	of agronomic recommendations appropriate for acidic soils, and low-moisture and waterlogged areas; • Refine packages of recommendations on integrated nutrient management practices including micronutrients appropriate for root crops; • Undertake systematic studies on crop physiology and generate information useful to enhance: plant efficiencies of water use, photosynthesis, and nutrient use; and crop growth and development and • Refine crop modeling tools that can be employed to forecast short- and long- term local climate patterns in, and also determine effects of climate change on root crops production systems.
5.2.4 Irrigation water and nutrient management			
Inadequate packages of recommendations on crop-water requirements and irrigation scheduling; and lack of data base on the available and/or potential irrigation schemes.	• Determine specific water requirements of root crops under different agro-ecologies and develop appropriate irrigation schedules; • Identify and map the existing irrigation schemes with respect to their suitability for production of root crops ;	• Refine and strengthen information on water requirements of root crops under different agro-ecologies and develop appropriate irrigation schedules • Develop water-efficient irrigation systems/ technologies (drip irrigation) and fertigation scheduling appropriate for cultivation of root crops in different agro-ecologies	• Refine and strengthen information on water requirements of root crops under different agro-ecologies and develop appropriate irrigation schedules • Refine and strengthen development of water-efficient irrigation systems/ technologies (drip irrigation) and fertigation scheduling appropriate for cultivation of root crops in different agro-ecologies

5.2.5 GIS and Agro-meteorology			
Lack of GIS-based information and knowledge for: timely operation of farm practices and suitability map	• Conduct spatial suitability analyses and develop suitability map of root crops as distributed across the various AEZs; • Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall and irrigation water requirements for production of root crops under irrigated and rain-fed conditions across different agro-ecologies.	• Refine information on modeling that can be employed to forecast local climate patterns in terms of seasonality of rainfall and irrigation water requirements for production of root crops under irrigated and rain-fed conditions across different agro-ecologies; • Develop integrated management practices fostering crop adaptation to climate change.	• Refine information on modeling that can be employed to forecast local climate patterns in terms of seasonality of rainfall and irrigation water requirements for production of root crops under irrigated and rain-fed conditions across different agro-ecologies; • Develop integrated management practices fostering crop adaptation to climate change.
5.2.6 Technology multiplication and seed research			
Lack of involvement of seed enterprises; shortage of planting material of early-generations; limited technical support to farmers and seed-growers; lack of recommendations on storage systems and awareness about the importance of disease- and pest- free planting material .	• Create awareness among seed-producing public and private enterprises and other stakeholders on the importance and business potential of producing good-quality planting materials of root crops using different formal and informal media of information-dissemination such as: workshops, discussion fora, field days, mass media, information leaflets and booklets, etc.; • Create awareness among farmers and extension experts and development agents (DAs) on the importance of using planting materials of root crops that are free from diseases and insect pests; and provide intensive trainings; • Produce and provide, to formal and/or informal seed-growers, sufficient amount of initial materials of early-generation seeds ; • Employ modern techniques and tools of biotechnology and tissue culture to identify and produce disease-free planting	• Keep creating awareness among seed-producing public and private enterprises and other stakeholders on the importance and business potential of producing good-quality planting materials of root crops using different formal and informal media of information-dissemination such as: workshops, discussion fora, field days, mass media, information leaflets and booklets, etc.; • Keep creating awareness among farmers and extension experts and development agents (DAs) on the importance of using planting materials of root crops that are free from diseases and insect pests; and provide intensive trainings; • Produce and provide, to formal and/or informal seed-growers, sufficient amount of initial materials of early-generation seeds; • Employ modern techniques and tools of biotechnology and tissue culture to identify and produce disease-free planting materials and • Strengthen information on storage systems appropriate for maintaining good-quality	• Keep creating awareness among seed-producing public and private enterprises and other stakeholders on the importance and business potential of producing good-quality planting materials of root crops using different formal and informal media of information-dissemination such as: workshops, discussion fora, field days, mass media, information leaflets and booklets, etc.; • Keep creating awareness among farmers and extension experts and development agents (DAs) on the importance of using planting materials of root crops that are free from diseases and insect pests; and provide intensive trainings; • Produce and provide, to formal and/or informal seed-growers,

	materials and • Establish storage systems appropriate for maintaining good-quality standards of planting materials of root crops.	standards of planting materials of root crops.	sufficient amount of initial materials of early-generation seeds; • Employ modern techniques and tools of biotechnology and tissue culture to identify and produce disease-free planting materials and • Refine and fine-tune recommendations on storage systems appropriate for maintaining good-quality standards of planting materials of root crops.
5.2.7 Agricultural economics			
Limited information on: characterization and diagnostics of farming systems; adoption and impact of technologies; and value chains, marketing and market efficiencies	• Undertake characterization and diagnosis of the farming systems involving root crops and document the socio-economic and cultural values and constraints; • Undertake studies on the rate of adoption and impacts of improved technologies of root crops; • Conduct crop-specific analysis of value-chains and determine market efficiencies in different root crops-growing parts of the country; • Develop systems of generating and communicating market information to different actors in the value chains of root crops; • Analyze the performance of agricultural support services (credit institutions, seed production systems, etc.,) affecting uptake and utilization of technologies of root crops and • Undertake studies on policy options that	• Update the information on characterization and diagnosis of the farming systems involving root crops and document the socio-economic and cultural values and constraints ; • Undertake studies on the rate of adoption and impacts of improved technologies of root crops; • Conduct crop-specific analysis of value-chains and determine market efficiencies in different root crops-growing parts of the country; • Develop systems of generating and communicating market information to different actors in the value chains of root crops; • Analyze the performance of agricultural support services (credit institutions, seed production systems, etc.,) affecting uptake and utilization of technologies of root crops and • Undertake studies on policy options that can positively influence root crops production and marketing.	• Update the information on characterization and diagnosis of the farming systems involving root crops and document the socio-economic and cultural values and constraints; • Undertake studies on the rate of adoption and impacts of improved technologies of root crops; • Conduct crop-specific analysis of value-chains and determine market efficiencies in different root crops-growing parts of the country; • Develop systems of generating and communicating market information to different actors in the value chains of root crops; • Analyze the performance of agricultural support services (credit institutions, seed

	can positively influence root crops production and marketing.		production systems, etc.,) affecting uptake and utilization of technologies of root crops and • Undertake studies on policy options that can positively influence root crops production and marketing.
5.2.8 Agricultural extension and gender			
Inadequate systems of: technology demonstration and popularization, and forward and backward flow of information and feedback; and limited gender mainstreaming	• Conduct participatory demonstration and popularization of available technologies and gathering feedbacks from stakeholders at different levels and agro-ecologies; • Create awareness and identify technology-cum-information dissemination and popularization methods enhancing production and consumption of root crops; • Establish a network of platforms serving various interests of stakeholders in major root crops- growing areas of the country and • Mainstream gender in the processes of development and adoption of technologies; and production, marketing and utilization of root crops.	• Conduct participatory demonstration and popularization of available technologies and gathering feedbacks from stakeholders at different levels and agro-ecologies; • Strengthen awareness creation and technology-cum-information dissemination and popularization methods enhancing production and consumption of root crops; • Strengthen the network of platforms serving various interests of stakeholders in major root crops- growing areas of the country and • Strengthening mainstreaming gender in the processes of development and adoption of technologies; and production, marketing and utilization of root crops.	• Conduct participatory demonstration and popularization of available technologies and gathering feedbacks from stakeholders at different levels and agro-ecologies; • Strengthen awareness creation and technology-cum-information dissemination and popularization methods enhancing production and consumption of root crops; • Strengthen the network of platforms serving various interests of stakeholders in major root crops- growing areas of the country and • Strengthening mainstreaming gender in the processes of development and adoption of technologies; and production, marketing and utilization of root crops.
5.2.9 Agricultural mechanization			
Lack of technologies for pre- and post-harvest operations; limited supply of prototypes;	• Inventorize and test available pre and post-harvest tools and machineries for root crops (row planters, harvesters, choppers, millers, slicers, etc.);	• Refine available pre and post-harvest tools and machineries for root crops (row planters, harvesters, choppers, millers, slicers, etc.); • Adopt and adapt agricultural mechanization	• Develop new pre and post-harvest tools and machineries for root crops (row planters, harvesters, choppers, millers, slicers, etc.);

inadequate information on efficiencies of machineries at hand; and lack of participatory.	• Adopt and adapt agricultural mechanization technologies appropriate for small-scale farmers growing root crops.	technologies appropriate for small-scale farmers growing root crops.	• Adopt and adapt agricultural mechanization technologies appropriate for small-scale farmers growing root crops.
5.2.10 Food science, postharvest management and value addition			
Lack of recommendations/ information on: storage methods; nutritional quality and anti-nutritional contents; food fortification and value addition.	• Determine the nutritional and anti-nutritional contents (starch, protein, vitamins, minerals, HCN, magnesium oxalate, etc.) of the existing varieties and elite materials of root crops; • Assess the causes and determine extent of postharvest losses of root crops across different production areas and market outlets; and develop post-harvest management technologies (harvesting, storage, handling, packaging, processing, preservation methods, etc.) and • Establish methods of developing consumer-driven and value-added alternative products of root crops including methods of food fortification.	• Strengthen determination of the nutritional and anti-nutritional contents (starch, protein, vitamins, minerals, HCN, magnesium oxalate, etc.) of root crops; • Fine-tune the results and information on the causes and determine extent of postharvest losses of root crops across different production areas and market outlets; and develop post-harvest management technologies (harvesting, storage, handling, packaging, processing, preservation methods, etc.) and • Establish methods of developing consumer-driven and value-added alternative products of root crops including methods of food fortification.	• Strengthen determination of the nutritional and anti-nutritional contents (starch, protein, vitamins, minerals, HCN, magnesium oxalate, etc.) of root crops; • Fine tune the results and information on the causes and determine extent of postharvest losses of root crops across different production areas and market outlets; and develop post-harvest management technologies (harvesting, storage, handling, packaging, processing, preservation methods, etc.) and • Establish methods of developing consumer-driven and value-added alternative products of root crops including methods of food fortification.
5.2.11 Capacity building			
Inadequate resources • Physical • Human • Finance	• Upgrade the existing, establish new, and research facilities (mini-biotech laboratories, cold rooms, stores, green houses, offices, land and irrigation for seed production, etc.); • Provide sufficient field vehicles and farm implements at coordinating and selected implementing centers;	• Upgrade the existing, establish new, and research facilities (mini-biotech laboratories, cold rooms, stores, green houses, offices, land and irrigation for seed production, etc.); • Provide sufficient field vehicles and farm implements for implementing centers; • Strengthen the number of research and technical staff through recruitment;	• Upgrade the existing, establish new, and research facilities (mini-biotech laboratories, cold rooms, stores, green houses, offices, land and irrigation for seed production, etc.); • Provide sufficient field vehicles and farm implements for

	• Strengthen the number of research and technical staff through recruitment • Improve technical cunning of the research staff through short- and long-term trainings tailored to upgrade research skills and qualifications • Provide incentives to retain staff and • Allocate sufficient budget for research and capacity building and improve efficiency of utilization.	• Improve technical cunning of the research staff through short- and long-term trainings tailored to upgrade research skills and qualifications; • Provide incentives to retain staff and • Allocate sufficient budget for research and capacity building and improve efficiency of utilization.	implementing centers; • Strengthen the number of research and technical staff through recruitment; • Improve technical cunning of the research staff through short- and long-term trainings tailored to upgrade research skills and qualifications; • Provide incentives to retain staff and • Allocate sufficient budget for research and capacity building and improve efficiency of utilization.
5.2.12 crosscutting themes			
Gender	• Organize gender disaggregated data for technology dissemination, adoption and impact of technologies; and in the course of technology demonstration, popularization, and training ensure that all female-headed households and at least 30% of beneficiaries to be women from male-headed households.		
Climate change	• Develop research programs that would adequately address the challenge to increase resilience of vulnerable communities.		
Knowledge management	• Consider modern facilities of ICT instrument in knowledge and information transfer and sharing processes.		

The Next Steps

Following the approval of the strategy document by the top management of EIAR, it is essential to prepare the implementation plan, without which this strategy is not going to reach fruition. The implementation plan document will be developed using a common Guideline adopted by the EIAR Planning, Monitoring and Evaluation Directorate to provide guidance to research teams develop implementation plans. The implementation plan will thus come out as Volume II of the research strategy, which will serve as the blueprint to guide the National Root Crops Research for the next fifteen years (2016-2030). The major contents of the implementation plan will revolve, among others, around the following topics:

- Develop implementation plan;
- Develop monitoring and evaluation plan;
- Develop impact assessment plan and
- Develop reassessment plan for the strategy .

Sub-Tropical Fruits Research Strategy

Introduction

The fruit crops citrus, avocado, mango, grapes and guava constitute EIAR's Sub-tropical Fruit Crops Research Program for which Ethiopia is endowed with agro-ecologies favorable to grow them. Nowadays fruits are becoming important crops as the number of small-holder fruit producers has been increasing at an average rate of 12% per year over the last half a decade or so and currently ca. 3.6 million households are producing fruits on average plot sizes of 120m^2. Annually about 43,500 ha of land is devoted to fruit production and a total of about 261,000 metric tons is produced from which less than 2% is exported. The sub-tropical fruits avocado, mango and citrus together contribute for more than 80% of the land and 95% of the produce. Nevertheless, the size of land and volume of production logged under sub-tropical fruits clearly represent only a diminutive proportion of the potential that the country could reap from this important sub-sector as a consequence of multiples of interactive factors hindering its expansion.

In pursuit to reverse the dire situation of the horticulture sub-sector in general and that of the fruits in particular, the Government of Ethiopia has taken a number of measures that would embolden the industry. Fundamental among these bold measures is the establishment of the Ethiopian Horticulture Development Agency. The government has also introduced attractive packages of incentives for both local and foreign investors engaged in horticultural ventures. These include such privileges as: provision of loans up to 70 percent of the investment capital; duty-free import of farm implements and equipment; and a five-year tax holiday to export-oriented growers. The government has also set a target of increasing production of fruits and vegetables from 1.28 million tons to 5.91 million tons by doubling the average productivity from 84 to 165 quintals per hectare and expanding land from 152.6 to 236 thousand hectares during the Second Growth and Transformation Plan (GTP II) period.

In order to achieve this ambitious plan, it is critical that two conditions must be fulfilled instantaneously. First, beside increasing production by the smallholders sector, large- and medium- size orchards producing sub-tropical fruits have to increase substantially. Second both sectors need to be assisted by the research system to get access to improved technologies, agricultural innovation, information and knowledge so that they would be able to produce high- quality and volume of products that are competent in both domestic as well as export markets. For the research system to attune itself with such a vital role of developing the sub-tropical fruits sub-sector, EIAR has decided to develop this long-term research strategy traversing fifteen years.

The strategy is organized in six major chapters whereby this background section together with descriptions of the rationale, vision, mission, goal and objectives constitute the introductory chapter 1. Chapter 2 provides an overview of the importance of sub-tropical fruit crops in the Ethiopian agriculture; and food and nutrition security. Chapter 3 briefly discusses the situation analysis undertaken by assessing the internal environment as well as the external one involving all the key stakeholders to capture their reflections, concerns and desires. In chapter 4 are presented the critical issues that have been sifted out from the

situation analysis and articulated as key challenges facing the sub-tropical fruit crops research program. Chapter 5 discusses the actual strategic interventions to be pursued under the various thematic areas of the research to tackle the critical issues identified. Chapter 6 provides key elements of follow up documents that need to be worked out in the next steps as they are prerequisites for effective implementation of the strategy.

Rationale

Currently, the sub-tropical fruits industry is not contributing to its level best albeit the potential it can have to: ensure food and nutrition security for millions of small-scale farming households; strengthen the opportunity for job creation and income generation; foster expansion of agro-industries, agri-business and import substitution; diversify the base for foreign earnings; and stabilize the macro-economy in general. Cognizant of its potential, the Government of Ethiopia has put in place conducive policy and regulatory frameworks that can be instrumental to propel the progress of the sub-sector which in turn would benefit small-scale and commercial growers, agro-industries, exporters and consumers of sub-tropical fruits.

Therefore, the need for maximizing utilization of potential agro-climatic, physiographic and hydrologic conditions of the country to increase production, productivity and marketability of sub-tropical fruit crops is a matter of urgency. In the present context though not only is wide the gap between what is available at research level and how much of that is being used by the farmer; but also are little the results attained thus far by the research system in comparison with the potential that could be realized from these crops. In order to create a condition where these divergent scenarios could converge and thus the commodities' potential could best be exploited, it is absolutely necessary to develop a well-defined and an all-inclusive research strategy representing and addressing the interests of all the key stakeholders involved in the value chains of the crops. Such a strategy not only creates a stronger cohesion and partnership among stakeholders but also serves as a roadmap to: guide the research program planning and implementation in line with the objectives and targets of GTP-II and that of EIAR; track records of results and lessons; and mobilize resources from national and/or international sources. It is with this rationale that the National Sub-tropical Fruit Crops Research Program (NStFCRP) - Team has developed this Research Strategy to achieve a common vision and objectives.

The NStFCRP-Team has a strong conviction that a thriving future for the commodities can be achieved only if it involves meaningful collaborations between farmers, input suppliers, exporters, actors in agribusiness and agro-industry, traders, technicians, scientists, and others engaged in the value chains. To this end, the research team has formulated a set of principles and values that reflect its vision, mission, goal and objectives underpinning its commitments and desires as indicated below.

Vision

The vision of the National Sub-tropical Fruits Research Program is to become a leading agricultural program providing technological innovations and knowledge that can significantly contribute to improved livelihoods.

Mission

The mission of the NStFCRP is to generate, develop, adapt and promote competitive agricultural technologies, innovations, information and knowledge for improving productivity, nutritional quality and sustainable development of agriculture, agribusiness and agro-industry, supporting attainment of self-reliance and import substitution, and broadening the opportunity to exploit the potential export markets and income generations for households and the country.

Goal

The goal of the NStFCRP is to contribute to the EIAR's role towards the achievement of the sectorial objectives of (i) ensuring food security, (ii) sustainable delivering of raw materials for agro-industries and import substitution, (iii) expanding the bases for the country to gain foreign earnings from agricultural exports, and (iv) increasing livelihood resiliency and environmental sustainability while reducing vulnerability to climate change.

Objectives

The overall objective of the NStFCRP is to increase the production, productivity and quality of sub-tropical fruits through multidisciplinary and participatory research approach leading to their increased share in the national economy and advancement by understanding and applying new approaches in the whole set of the industry. Specific objects of the program, among others, include the following:

- To collect, introduce, characterize and develop varieties adaptable to different ecological and agronomic scenarios;
- To develop, adapt and promote improved agronomic and other technological packages suitable for sub-tropical fruits;
- To develop, adapt and promote conventional as well as modern techniques and methods of efficient multiplication of planting material;
- To develop, adapt and promote integrated and sustainable pest (diseases, insects, nematodes, vertebrates and weeds) management packages and
- To develop, adapt and promote appropriate postharvest (maturity indices, harvesting, handling, storage, processing and utilization) management technologies.

Importance of Sub-tropical Fruits

Fruit crops are sources of vitamins, minerals, and dietary fiber. Furthermore, vitamin ***A*** deficiency which is a major public health problem in Ethiopia predisposing children to increased risk of morbidity, mortality and disability, could in part be overcome by consuming fruits. Because many areas in Ethiopia are bestowed with a rather more Mediterranean-type of climate, they are remarkably suitable for production of sub-tropical fruits such as citrus, avocado, mango, grapes, guava and others; which are naturalized to the Ethiopian agro-ecologies.

Cultivation of fruit crops in Ethiopia probably started in the fourth century with the

introduction of raisins (dried grapes), for serving the 'sacred meal' of Holy Eucharist in the church. Citrus and mango were introduced in the late 1960s and the early 1970s. Production of the crops is concentrated mainly in East Harrerghe; East Shewa; West Shewa; Arsi; SNNPR particularly Wolaita and Sidama Zones; Diredawa; Harari; South Tigray and West Gojam regions. Avocado covers about 13,678 ha of small-scale holdings with a production of 54,882 tons. Mango covers ca. 12,694 ha of land and 109,499 tons of production. The area under citrus is estimated to be about 8.5 thousand hectares; more than 80% of which is by small-holders producing annually about 72,458.8 tons of fruits; while the remaining area is under commercial plantation with annual production estimated at 20,177 tons.

Fruit processing in Ethiopia is limited mainly to extraction of fresh juice and jams with the exception of the few agro-industries involved in wineries. Awash and Castel Wineries and few growers produce grapevines for the production of wine, fresh table and raisin grapes; *Horizon* processes orange concentrate, jams and squash, and guava nectar; Africa Juice produces blended-concentrate from mango, passion fruit and papaya. Nevertheless, a range of fruit juices are imported into the country at a cost of more than 8.5 million USD annually. Both fresh and processed fruits including the Ethiopian wine have huge potential for domestic and export markets. The major export destinations are Djibouti, Sudan and Somalia, United Arab Emirates, United Kingdom, the Netherlands, Belgium, Middle-East (Yemen, Saudi Arabia), and the Russian Federation; the contribution is very weak though. Fruits and vegetable products generate annually about 877 million Ethiopian birr.

Environmentally, fruit crops have the ability to modify the micro-climate in terms of temperature, relative humidity and wind speed among other things. On farmlands, they can also improve soil permeability, aggregate stability, water holding capacity and soil temperature regimes. Integrating fruit crops in rangelands can also increase total productivity, reduce sensitivity to short-term fluctuations of climatic conditions, spread ecological risks through species diversity and improve system sustainability. Furthermore, fruit trees can provide alternative land-use options and aid more sustainable farming systems.

Situation Analysis

Two categories of forces and factors influencing the conception, formulation, action and implementation of the strategy were analyzed as external and internal factors. The external factors (influences that are outside the research system) represent both the interests of stakeholders that the research should serve and the potential role that they can play to complement or synergize the research. Specific situations or stakeholders' interests that hold back research stride or the research falls short to positively respond to, represent the challenges (C); while those that create motivation for the research represent the opportunities (O). Therefore, the situation analysis of the external factors essentially examined Opportunities and Challenges (OC) presented from the existing Political /Policy /Legal, Economic, Educational, Socio-cultural, Technological/ Technical, and Environmental (PEST) perspectives of the factors. Almost all key stakeholders, notably

the Ministries of: Agriculture and Natural Resources, Trade and Industries; exporters; private industries; farmers' unions; various relevant technical units of EIAR; the Regional Research Institutes and centers; and Higher Learning Institutions involved in Sub-tropical Fruit Crops research have taken part in the process.

Analysis of the internal situation (influences that are outside the research system) was made by scrupulously examining whether or not there exists the capacity within the research system that can readily be deployed by the team to deliver outputs or promptly respond to stakeholders' quests or challenges. While the presence of such a capacity denotes the strength (S) of the team; the capacity which is required to deliver desirable outputs but falls short to exist represents the weakness (W). Therefore, analysis of the situation of internal factors examined Strengths and Weaknesses (SW) of the research team in terms of the existing resources (human, physical and fiscal); inter- and intra-disciplinary integrations, complementarities and synergies; availability of technologies, information and knowledge; and organization of internal system, and geographic coverage of the research program.

The results from the situation analysis were finally consolidated in a form of metrix whereby prevailing strengths, weaknesses, opportunities, and challenges (SWOC) were narrated with respect to their relevance to the various thematic areas that the research team is engaged in. From the situations narrated as such then were formulated the issues that the research system needs to address in the short-, medium-, and long- term plans. Experiences of other countries with respect to the level they have reached in research and development aspects of Sub-tropical fruit crops were also examined to set a benchmark for the strategy.

Strategic Issues and Strategic Interventions

The major strategic thematic areas identified for the Sub-tropical Fruit Crops Research Program include: (1) Genetics and breeding; (2) Crop protection; (3) Agronomy and physiology; (4) Irrigation and water management; (5) Food science, postharvest management and value addition; (6) Agricultural mechanization; (7) GIS and Agro-meteorology; (8) Technology multiplication; (9) Agricultural economics; (10) Agricultural research extension and gender; (11) Capacity building; and (12) Additional cross-cutting themes. Specific strategic issues pertaining to each thematic area are presented under Table 1.

Most of the research issues identified to be addressed by the sub-tropical fruit crops research team are multi-institutional, multi-thematic, multidisciplinary, participatory, and need to be implemented in collaboration with farmers, extensionists and a wide range of other partners to be involved in the whole spectrum of the value chains. The research themes are built on the disciplinary as well as crosscutting themes briefly discussed hereunder. The strategic interventions proposed to tackle each of the issues identified for each theme, and need to be implemented during the next fifteen years on the: short-, medium- and long- term basis, are presented in Table 1 following the narrations of the disciplinary and cross-cutting thematic areas.

Research Themes

Genetics and breeding

In the years ahead, the sub-tropical fruit crops sub-sector foresees a steady demand for varieties with higher and more stable yields and acceptable quality. To keep pace with this demand, much of the focus will be on developing new varieties that are high yielding, adapted to a variety of environments, and resilient in the face of multiple stresses such as climate change, emergence of new pests and diseases, and other biotic and a biotic factors. The strategy will generally seek to accelerate crop improvement by using both conventional and modern methods and technologies that make possible handling of large volumes of genetic material and select with greater precision. This will involve stronger integration of conventional plant breeding approaches with modern tools and methods of biotechnology.

Crop protection

To make crop production more eco-efficient is to achieve yield stability and reduce the chances of crop failure due to diseases and other pests, whose dynamics are shifting as a result of climate change. To this end, the research will focus on both host plant resistance and biological control with greater emphasis to integrated approaches of controlling diseases, insect pests, weeds and vertebrate pests through Integrated Pest Management (IPM) systems.

Agronomy and physiology

Keeping the principle of eco-efficiency, the agronomy and crop physiology endeavor will focus towards developing improved crop and soil management practices that open the way for optimal expression of genetic potential of varieties and enhancing the physiological and agronomic efficiency of the crops.

Irrigation water and nutrient management

Development of water-efficient management practices including micro-irrigation, fertigation; irrigation scheduling, etc. constitute arears of intervention related to production of sub-tropical fruit crops as they form integral components of league of crops that are best fitting for production of high-value crops under irrigation conditions.

Food science, postharvest management and value addition

The sub-tropical fruit crops have a great deal of potential in the food industry. It is therefore, essential to work on chemical characterization and profiling of the available varietes and eventually the genepool for nutritional as well as industrial values. It is also critical to develop recommendations on post-harvest technologies that would improve shelf life of the produce. Establishing alternative ways of processing the produce in view of increasing their shelf life will also open up a new vista of value addition and product diversification and thus better market opportunities for producers and options of choices for consumers.

Agricultural mechanization

The main challenges associated with agricultural machinery and post-harvest handling is the fact that producers in Ethiopia had little opportunity to employ small-scale farm implements, water pumps for irrigation, means of transportation, and storage structures that are appropriate for sub-tropical fruits. Both pre- and post- harvest operations are done manually and losses in both quantities and qualities associated with manual practices are often appalling. It is therefore, imperative to consider this field of research in this research strategy.

GIS and agro-meteorology

In formulating strategic interventions to be harnessed for achieving the objectives stipulated from the outset, it will be given due attention to GIS and agro-meteorology for better understanding of the dimensions of local climate and farming systems (physical climate, social, economic, farming systems, etc.) for targeting and developing the right technology for the right environment.

Technology multiplication and seed research

The core of research activities envisioned by the technology multiplication and seed research component of the strategy will be to: identify key problems associated with producing sufficient quantity and quality of initial material by generating basic information that would help to develop technologies addressing the challenges; adopt advanced tools of tissue culture for developing disease-free planting material of sub-tropical fruit crops; identify and adopt good practices of technology multiplication for large-scale production of the crops; and devising an internal system whereby expeditious multiplication of high-quality planting material would be effected in order to meet ever growing demand.

Agricultural economics

Agricultural economics is among the core themes of research as it plays a vanguard role in linking the biological sphere of the research and the economic validity of the results when actually being implemented by the farmer or other targets in the recommendation domains. Furthermore, it has also a key role to play in addressing policy issues that are instrumental in developing and promoting efficient, functional and sustainable value chains of the commodities constituting the Sub-tropical Fruit Crops Research Program.

Agricultural extension and gender

The agricultural extension and gender component of the research brings in stakeholders together to formulate relevant research agenda as it does also take out promising research results to the demonstration and extension processes. Notwithstanding the role the extension component plays in addressing the social aspects of the research, it is the main channel for the two-way flow of information between the research system on one hand and the end users of the research results on the other. Therefore, addressing issues related to socio-economic and research extension in the strategy is vital to attain the successes that the research team envisages. It will also be crucial to address issues related to gender equality and inclusiveness of the research process in general through this component.

Capacity building

Two important issues were identified under this topic: (i) the need for strengthening the capacity of the research team; and (ii) the stakeholders involved in the value chains in general need to have a strong, functional, influential and sustainable forum that will shape up the future of the research, production, processing, trade, and consumption of the commodities.

Crosscutting themes

Gender: The role of women in the agricultural system is critical as women contribute 70 percent of farm labour at harvesting and in post-harvest activities. But women farmers have only limited access to resources, services, land and credit. Unequal gender relations often make women more vulnerable to the effects of poverty, land degradation, and climate change. If the gender gap were eliminated, FAO asserts that total agricultural output would increase. Cognizant of this, the strategy upholds integration of gender concerns into research objectives, technology development, extension, and evaluation frameworks.

Climate change: In Ethiopia, climate change is already having an impact on the livelihoods of different communities in different corners of the country. Therefore, the research strategy will place due considerations to availing technologies that would help actors in the value chains to respond to climate change through adaptation and/or mitigation approaches.

Knowledge management (KM): Through KM interventions aided by new information technologies, it is possible to help improve smallholders' access to resources that help them improve their farm productivity and competitive ability. KM will also help to create research products in a more collaborative manner that makes them more suitable for diverse audiences. For this purpose, the research team will make results more readily available by spearheading formations of multi-stakeholder platforms that facilitate interaction and promote learning for change, mentoring, and networking.

Strategic Interventions

Table 1.Strategic interventions planned to address critical issues facing the National Sub-tropical Fruit Crops Research Program in the short-, medium- and long- terms

Thematic areas	Strategic Interventions		
	Short term (5 years)	**Medium term (10 years)**	**Long term (15 years)**
5.2.1 Genetics and breeding			
Lack of improved scion and rootstock varieties; narrow local genetic base; little/no use of biotechnological tools for variety development and maintenance; and lack of germplasm maintenance system	• Broaden the genetic bases of avocado and mango through collection and characterization of local clones; and those of citrus and grapevine through introduction of germplasm from external sources; • Introduce and adapt new scion varieties of grapevine and citrus with high yield, quality and stress- resistance/tolerance and suitable for fresh market and processing; and register those introduced heretofore; • Introduce and adapt rootstock varieties resistant/tolerant to biotic and abiotic stresses (soil-born diseases and others), with genetic capacity to impinge dwarfing and acquiescence to high-density planting systems; and register those introduced heretofore and • Maintain and conserve improved varieties and elite lines on selected research fields	• Introduce and adapt new scion varieties of grapevine and citrus with high yield, quality and stress resistance/tolerance and suitable for fresh market and processing; • Introduce and adapt new rootstock varieties resistant/tolerant to biotic and abiotic stresses (soil-born diseases and others), with genetic capacity to impinge dwarfing and acquiescence to high-density planting systems; • Undertake pedigree selections of desirable genotypes from pertinent crosses of elite clones; • Carryout mutation breeding on citrus and grapevine for improving quality traits; • Carryout genomic selection and molecular characterization of local avocado and mango germplasms and • Maintain and conserve improved varieties and elite lines on selected research fields.	• Introduce and adapt new scion varieties with high yield, quality and stress resistance/tolerance that are suitable for fresh market and processing; • Develop improved avocado and mango varieties with high- yield, quality and biotic and abiotic resistances/tolerances from clones characterized and selected using biotech tools (molecular characterization, and genomic and marker-assisted selection techniques); • Carryout extensive planned hybridizations among and between local and introduced clones to expedite introgression of desirable traits onto established cultivars and/or to develop new varieties and • Develop and employ in-vitro conservation techniques and conserve germplasms on selected research fields.
5.2.2 Crop protection			
Lack of information on biology and ecology of major pests; and inadequate IPM methods against major	• Survey and identify pests of major sub-tropical fruits in different agro-ecologies; • Study the biology and ecology of pests identified to be economically important; • Test and register introduced pesticides and bio-control methods targeted against major	• Optimize and employ molecular (PCR, RT-PCR, etc.) and serological (ELISA) techniques for diagnosis and studying the biology of disease- and insect pests; • Introduce and adapt IPM packages, IPM-compatible agrochemicals, and biological control	• Generate information on biology and physiology of pests on major fruit crops using molecular (PCR, RT-PCR, etc.) and serological (ELISA) diagnostic techniques; • Develop technologies/techniques and methods of risk assessment and prediction

diseases and insect pests	pests of sub-tropical fruits and • Introduce, adapt and develop options of IPM packages against major pre- and post- harvest pests of sub-tropical fruits.	options against major and emerging pests of sub-tropical fruits and • Develop novel botanicals and bio-control options for major pests of sub-tropical fruits.	of pest occurrences; • Develop and introduce new IPM packages for controlling newly-emerging pests and • Develop and enhance the use of biological pesticides, novel microbial products and botanicals against major pests of sub-tropical fruits.
5.2.3 Agronomy and physiology			
Limited information on: nutrient requirements for conventional and organic fruit production, cropping systems, phenology, canopy and fruit regulation practices; and cropping systems fostering nutrient recycling and environmental sustainability	• Develop INM (integrated nutrient management) packages for systems of conventional cultivation of major sub-tropical fruits; • Introduce, adapt and standardize training, pruning and flower management practices for sub-tropical fruit crops; • Study, evaluate and determine the phenology of sub-tropical fruits under different agro-ecologies and • Develop cropping systems, incorporating sub-tropical fruit crops, enhancing efficient utilization and management of natural resources under different agro-ecologies.	• Optimize INM packages for intensive cultivation of sub-tropical fruits in different agro-ecologies and growing scenarios (irrigated vs rainfed; cropping systems,.); • Introduce, adapt and standardize organic (bio- and organic- fertilizers, cultivation system, etc.) nutrient management technologies; • Introduce and standardize improved planting systems, and canopy and flower/fruit regulation practices; • Study, evaluate and determine the phenology of sub-tropical fruits under different agro-ecologies and • Fine tune recommendations on cropping systems intended for efficient utilization and management of natural resources under different agro-ecologies.	• Develop new INM technologies for intensive cultivation of sub-tropical fruits in different agro-ecologies and growing scenarios (irrigated vs rainfed; cropping systems,.); • Adapt nutrient diagnostic tools for efficient nutrient management; • Refine and strengthen recommendations on organic (bio- and organic- fertilizers, cultivation system, etc.) nutrient management technologies; • Introduce and develop standardized high-density planting systems, and canopy and flower/fruit regulation practices; • Introduce and develop technologies for manipulating/regulating plant phenology under different growing agro-ecologies and • Establish standardized cropping systems entailing efficient utilization and management of natural resources under different agro-ecologies.
5.2.4 Irrigation water and nutrient management			
Lack of crop-specific water requirements; irrigation scheduling; and water-efficient of irrigation systems appropriate for different	• Determine specific water requirements and irrigation scheduling for citrus, mango, grape and avocado across different agro-ecologies; • Introduce and adapt water-efficient irrigation systems/ technologies (drip irrigation) and	• Develop specific water requirements and irrigation scheduling for citrus, mango, grape and avocado across different agro-ecologies; • Strengthen developing water-efficient irrigation systems/ technologies (drip irrigation) and	• Refine and strengthen development of specific water requirements and irrigation scheduling for citrus, mango, grape and avocado across different agro-ecologies; • Refine and strengthen development of

AEZs	fertigation scheduling appropriate for cultivation of selected sub-tropical fruits in different agro-ecologies.	fertigation scheduling appropriate for cultivation of sub-tropical fruits in different agro-ecologies.	water-efficient irrigation systems/ technologies and fertigation scheduling appropriate for cultivation of sub-tropical fruits in different agro-ecologies.
5.2.5 Food science, postharvest management and value addition			
Heavy post-harvest losses and lack of management technologies; low quality and limited value added products; and lack of waste management practices and technologies	• Assess the causes and determine extent of postharvest losses of sub-tropical fruit crops across different production areas and market outlets; • Introduce and adapt post-harvest management technologies (harvesting, storage, handling, packaging, processing, etc.) for fresh market and processed fruit products; • Develop methods and techniques of producing semi-processed products of sub-tropical fruit crops for value addition; • Determine nutritional composition and quality of fresh and processed fruit products of sub-tropical fruits and • Identify causes and quantify magnitude of fruit wastage along the value chains of sub-tropical fruits and establish management practices and technologies that minimize wastage and open new ways of using the refuse for agricultural inputs.	• Develop affordable post-harvest management technologies of fruits for fresh market and processing; • Refine methods and techniques of producing semi-processed products of sub-tropical fruit crops for value addition; • Refine and compile nutritional composition and quality profiles of fresh and processed fruit products of sub-tropical fruits and • Refine waste minimization, management and utilization techniques/technologies and methods for agricultural use.	• Develop affordable post-harvest management technologies of fruits for fresh market and processing; • Develop methods and techniques of producing fully-processed sub-tropical fruit products for value addition; • Refine and compile nutritional composition and quality profiles of fresh and processed fruit products of sub-tropical fruits and • Develop waste management and utilization techniques/technologies and methods for different agricultural and industrial products.
5.2.6 Agricultural mechanization			
Limited use of small-scale harvesting, handling, packing and processing technologies	• Inventorize research-developed and locally available small-scale technologies, evaluate and promote those appropriate for pre and post-harvest management of sub-tropical fruits; • Adopt and adapt agricultural mechanization technologies appropriate for small-scale farmers growing sub-tropical fruits;	• Avail pre- and post-harvest mechanization technologies through adaptation to suit existing situations;	• Avail more advanced and appropriate pre- and post-harvest implements through adaptation to suit existing situations; • Adapt state-of-the-art technologies of pre- and post-harvest management and avail those which can make the country competent in the world market;

5.2.7 GIS and Agro-meteorology			
Lack of information on spatial suitability, climate characterization and modeling and adaptation responses	• Conduct spatial suitability analyses and develop suitability map of tropical fruit crops as distributed across the various AEZs and • Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall in meeting crop water requirements under rain-fed system across AEZs.	• Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall and irrigation water requirements under irrigated conditions and • Develop integrated management practices fostering crop adaptation to increased heat load in sub-tropical fruit plantations.	• Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall and irrigation water requirements under irrigated conditions and • Develop integrated management practices fostering crop adaptation to increased heat load in sub-tropical fruit plantations.
5.2.8 Technology multiplication and seed research			
Lack of standardized techniques and protocols for disease cleaning and mass propagation; and insufficient planting material of early generation clones	• Develop shoot tip and in-vitro mass propagation and disease-cleaning protocols for citrus; • Develop clonal rootstock multiplication and conventional mass propagation protocols for avocado and guava, respectively • Multiply good-quality initial planting materials through micro-propagation and conventional techniques and promote their distribution and • Establish scion banks of pedigree planting materials of improved varieties.	• Strengthen the development of shoot tip and in-vitro mass propagation and disease-cleaning protocols; • Develop standard clonal propagation techniques and protocols for rootstock multiplication; • Initiate mass multiplication of clonal rootstocks resistant to disease and abiotic stresses; • Establish protected blocks for maintaining mother stocks of scion and rootstock collections and • Undertake mass multiplication of good-quality planting materials through conventional and micro-propagation techniques and promote their distribution Undertake mass multiplication of good-quality planting materials through conventional and micro-propagation techniques and promote their distribution.	• Optimize in-vitro mass propagation and disease-cleaning protocols for the other sub-tropical fruits; • Strengthen mass multiplication of good-quality planting materials through conventional and micro-propagation techniques and promote their wide-scale distribution; • Strengthen mass multiplication of clonal rootstocks resistant to disease and abiotic stresses and • Strengthen maintenance of mother stocks of scion and rootstock collections in protected blocks.
5.2.9 Agricultural economics			
Limited information on value chains; marketing and issues of technology adoption and impacts	• Conduct crop-specific analysis of value-chains and determine market efficiencies in different sub-tropical fruit-growing parts of the country; • Develop systems of generating and communicating market information to different actors in the value chains of Sub-tropical fruits and	• Strengthen the study on the dynamics of value chains of selected Sub-tropical fruits; • Strengthen the systems developed to generate and communicate market information to different actors in the value chains of Sub-tropical fruits and • Strengthen studies on the rate of adoption and	• Strengthen the study on the dynamics of value chains of selected Sub-tropical fruits; • Strengthen the systems developed to generate and communicate market information to different actors in the value chains of Sub-tropical fruitsand • Strengthen studies on the rate of adoption

	• Undertake studies on the rate of adoption and impacts of technologies of Sub-tropical fruits (bananas, papaya and pineapple).	impacts of technologies of Sub-tropical fruits (bananas, papaya and pineapple).	and impacts of technologies of Sub-tropical fruits (bananas, papaya and pineapple).
5.2.10 Agricultural extension and gender			
Inadequate promotion and popularization of technologies; inadequate participatory technology development, evaluation, and adoption; limited gender mainstreaming in technology development and adoption, and production, marketing and utilization of sub-tropical fruits	• Create awareness and identify technology-cum-information dissemination and popularization methods enhancing production and consumption of Sub-tropical fruits in both rural and urban areas; • Establish a network of platforms serving various interests of stakeholders in major fruit growing areas of the country; • Adapt and disseminate best-bet practices on successful household-level establishment of cactus pear orchards and cactus moth and cochineal control methods in dryland areas and • Mainstream gender in the processes of development and adoption of technologies; and production, marketing and utilization of Sub-tropical fruits.	• Strengthen methods of awareness creation and technology-cum-information dissemination and popularization enhancing production and consumption of Sub-tropical fruits in both rural and urban areas; • Strengthen networks of platforms serving various interests of stakeholders in major fruit growing areas of the country; • Strengthen dissemination of best-bet practices on successful household-level establishment of cactus pear orchards and cactus moth and cochineal control methods in dryland areas and • Strengthen mainstreaming gender in the processes of development and adoption of technologies; and production, marketing and utilization of Sub-tropical fruits.	• Strengthen methods of awareness creation and technology-cum-information dissemination and popularization enhancing production and consumption of Sub-tropical fruits in both rural and urban areas; • Strengthen networks of platforms serving various interests of stakeholders in major fruit growing areas of the country; • Strengthen dissemination of best-bet practices on successful household-level establishment of cactus pear orchards and cactus moth and cochineal control methods in dry land areas and • Strengthen mainstreaming gender in the processes of development and adoption of technologies; and production, marketing and utilization of Sub-tropical fruits.
5.2.11 Capacity building			
Inadequate resources • Physical • Human • Finance	• Upgrade the existing and establish new and modern research laboratories (biotechnology, quality, soils, plant protection) and field infrastructure (irrigation, green and lath houses) at coordinating center; • Provide sufficient field vehicles and farm implements at coordinating and selected implementing centers; • Strengthen the number of research and technical staff through recruitment; • Improve technical cunning of the research staff through short- and long-term trainings tailored	• Establish new and modern research laboratories (tissue culture, quality, plant protection) and field infrastructure (irrigation and lath houses) for some implementing centers; • Equip adequately some selected centers with sufficient field vehicles and farm implements; • Improve the human resource through long-term trainings causing the research to become equipped with highly qualified multidisciplinary team of researchers; • Strengthen dexterity of researchers and technicians through short-term trainings in the	• Establishing new modern research laboratories (tissue culture, quality, plant protection) and modern infrastructure (irrigation and lath houses) for additional implementing centers; • Equip adequately some additional implementing centers with sufficient field vehicles and farm implements; • Improve the human resource through long-term trainings causing the research to become equipped with highly qualified multidisciplinary team of researchers;

	to upgrade research skills and qualifications; • Strengthen dexterity of researchers and technicians in application of specific topics like micro-grafting, postharvest, planting materials quality assurance, fertigation, knowledge management systems,; • Allocate sufficient budget for research and capacity building and improve efficiency of utilization; • Establish strong linkages between applied research and the private sector engaged in the fruits industry and • Mobilize additional project grants from resource partners and international research institutions.	application of in-vitro breeding techniques, post-harvest, planting materials quality, fertigation; • Create linkages with regional and international research, learning and development institutions; • Improve allocation and efficiency of utilization of budget for research and capacity building and; • Strengthen public-private partnership in applied research and • Mobilize additional project grants from resource partners and international research institutions.	• Strengthen skills of researchers and technicians through short-term trainings in the application of in-vitro conservation techniques and postharvest; • Strengthen linkages with regional and international research, learning and development institutions; • Improve the financial viability of the public research system; • Strengthen public-private partnership in applied research and • Mobilize additional project grants from resource partners and international research institutions.
5.2.12 crosscutting themes			
Gender	Organize gender disaggregated data for technology dissemination, adoption and impact of technologies; and in the course of technology demonstration, popularization, and training ensure that all female-headed households and at least 30% of beneficiaries to be women from male-headed households		
Climate change	Develop research programs that would adequately address the challenge to increase resilience of vulnerable communities		
Knowledge management	Consider modern facilities of ICT instrument in knowledge and information transfer and sharing processes		

The Next Steps

Following the approval of the strategy document by the top management of EIAR, it is essential to prepare the implementation plan, without which this strategy is not going to reach fruition. The implementation plan document will be developed using a common Guideline adopted by the EIAR Planning, Monitoring and Evaluation Directorate to provide guidance to research teams develop implementation plans. The implementation plan will thus come out as Volume II of the research strategy, which will serve as the blueprint to guide the National Sub-tropical Fruit Crops Research for the next fifteen years (2016-2030). The major contents of the implementation plan will revolve, among others, around the following topics:

- Develop implementation plan;
- Develop monitoring and evaluation plan;
- Develop impact assessment plan and
- Develop reassessment plan for the strategy.

Temperate Fruits Research Strategy

Introduction

Ethiopia is endowed with favorable agro-ecologies to grow a variety of temperate fruit crops, which are grouped into two as; Pome-fruits constituting Apple - Malus communis;Pear - Pyrus communis, and (Quince - Cydonia oblonga; and Stone-fruits Peach - Persica; Plum - Prunus domestica, (vi) Almond- Prunus communis,; Apricot - Prunus armeniaca,;Olive - Olea europaea; Strawberry - Fragaria vesca; Cherries - Prunus spp., and Nut-fruits (walnut and chestnuts). Nowadays, fruits are becoming important crops in Ethiopia as the number of small-holder fruit producers is increasing at 12% per year and ca. 3.6 million households are producing fruits on average plot sizes of 120m^2. The majority of producers and production land are linked with tropical fruits grown mainly in the hotter climates of the lowlands. Annually about 43,500 ha of land is devoted for production of fruits and a total of about 261,000 metric tons is produced from which less than 2% is exported. The size of land and volume of production logged under fruits clearly represent only a dismal proportion of the potential that the country could reap from this important sub-sector as a consequence of multiples of interactive factors hindering its expansion.

In pursuit of reversing the situation, Ethiopian government has taken a number of measures that would embolden the horticulture industry in general. Fundamental among these bold measures is the establishment of the Ethiopian Horticulture Development Agency. The government has also introduced attractive packages of incentives for both local and foreign investors engaged in the horticulture sector. These include such privileges as: provision of loans up to 70 percent of the investment capital; duty-free import of farm implements and equipment; and a five-year tax holiday to export-oriented growers. The government has also set a target to increase the production of fruits and vegetables from 1.28 million tons to 5.91 million tons by doubling the average productivity from 84 q to 165 q per ha and expanding land from 152.6 thousand ha to 236 thousand ha during the second growth and transformation plan (GTP II) period.

In order to achieve this ambitious plan, it is critical that two conditions must be fulfilled instantaneously. First, beside increasing the smallholders sector, the number of large- and medium- size orchards producing temperate fruits has to increase substantially; and second both sectors need to be assisted by the research system to get access to improved technologies, agricultural innovation, information and knowledge so that they would be able to produce high- quality and volume of products that are competent in both domestic as well as export markets. For the research system to attune itself with such a vital role of developing the temperate fruits sub-sector, EIAR has decided to develop this long-term research strategy traversing fifteen years.

The strategy is organized in six major chapters whereby this background section together with descriptions of the rationale, vision, mission, goal and objectives constitute the introductory chapter 1. Chapter 2 provides an overview of the importance of temperate fruit crops in the Ethiopian agriculture; and food and nutrition security. Chapter 3 briefly

discusses the process of situation analysis undertaken by assessing the internal environment as well as the external one involving all the key stakeholders to capture their reflections, concerns and desires. In chapter 4 are presented the critical issues that have been sifted out from the situation analysis and articulated as key challenges facing the temperate fruit crops research program. Chapter 5 discusses the actual strategic interventions to be pursued under the various thematic areas of the research to tackle the critical issues identified. Chapter 6 provides key elements of follow up documents that need to be worked out in the next steps as they are prerequisites for effective implementation of the strategy.

Rationale

Currently, the temperate fruits industry is not contributing to its level best albeit the potential it can have to: ensure food and nutrition security for millions of small-scale farming households; strengthen the opportunity for job creation and income generation; foster expansion of agro-industries, agri-business and import substitution; diversify the base for foreign earnings; and stabilize the macro-economy in general. Cognizant of its potential, the Government of Ethiopia has put in place conducive policy and regulatory frameworks that can be instrumental to propel the progress of the sub-sector which in turn would benefit small-scale and commercial growers, agro-industries and consumers alike of temperate fruits.

Therefore, the need for maximizing utilization of potential agro-climatic, physiographic and hydrologic conditions of the country to increase production, productivity and marketability of temperate fruit crops is a matter of urgency. In the present context though not only is wide the gap between what is available at research level and how much of that is being used by the farmer; but also are little the results attained thus far by the research system in comparison with the potential that these crops can provide. In order to create a condition where these divergent scenarios could converge and thus the commodities' potential could be exploited the best level possible, it is absolutely necessary to develop a well-defined and an all-inclusive research strategy representing and addressing the interests of all the key stakeholders involved in the value chains of the crops. Such a strategy not only creates a stronger cohesion and partnership among stakeholders but also serves as a roadmap to: guide the research program planning and implementation in line with the objectives and targets of GTP-II and that of EIAR; track records of results and lessons; and mobilize resources from national and/or international sources. It is with this rationale that the National Temperate Fruit Crops Research Program (NTFRP) - Team has developed this Research Strategy to achieve a common vision and objectives.

The NTFRP-Team has a strong conviction that a thriving future for the commodities can be achieved only if it involves meaningful collaborations between farmers, input suppliers, exporters, actors in agribusiness and agro-industry, traders, technicians, scientists, and others engaged in the value chains. To this end, the research team has formulated a set of principles and values that reflect its vision, mission, goal and objectives underpinning its commitments and desires as indicated below.

Vision

The vision of the National Temperate Fruits Research Program is to see the research system became center of excellence in temperate fruits research, technology, information and knowledge; and the country's temperate fruit sub-sector to be sustainably transformed into a vibrant and productive economic sector through increased productivity and improved quality

Mission

The mission of the NTFRP is to generate, develop, adapt and promote competitive agricultural technologies, innovations, information and knowledge for improving productivity, nutritional quality and sustainable development of agriculture, agribusiness and agro-industry, supporting attainment of self-reliance and import substitution, and broadening the opportunity to exploit the potential export markets and income generations for households and the country

Goal

The goal of the NTFRP is contribute to the EIAR's role towards the achievement of the sectorial objectives of (i) ensuring food security, (ii) sustainable delivering of raw materials for agro-industries and import substitution, (iii) expanding the bases for the country to gain foreign earnings from agricultural exports, and (iv) increasing livelihood resiliency and environmental sustainability while reducing vulnerability to climate change

Objectives

The overall objective of the NTFRP is to increase the production, productivity and quality of temperate fruits through multidisciplinary and participatory research approach that ultimately will lead to increased share of temperate fruits in the national economy and advancement in understanding and applying new approaches in the whole set of the industry. Specific objects of the program, among others, are:

- To develop technologies, empower smallholder growers and address major temperate fruits-related production, productivity and quality problems;
- To collect, characterize and conserve germplasm resources for research use through the participation of interdisciplinary teams;
- To forge collaborations and coordination of research projects and other related activities on temperate fruits being undertaken by research centers and higher learning institutions;
- To generate and popularize improved technologies addressing economic, market and nutritional needs;
- To ensure sustainable food and nutrition security, enhance import substitution, provide raw materials for agro-industries relying on temperate fruits, and broaden the base for the country to gain foreign earnings and
- To improve the livelihoods of producers as well as other actors involved in the value chains of temperate fruits.

Importance of Temperate Fruits

Temperate fruits especially apple was introduced into the tropical mountains of southwestern Ethiopia in the 1970's by missionaries; and essentially they are all introductions. Some productive low-chill apple trees have been restricted mainly to areas with a humid tropical mountain climate in the southern Ethiopia. The culture of temperate fruits is new to Ethiopia and the research hitherto was very much limited to identifying varieties adaptable to some target areas with a set of specific climatic factors. Properly designed and implemented fruit production schemes can help to: alleviate poverty; ensure food and nutrition security; improve livelihoods and employment; maintain ecosystems and good health; conserve biodiversity; and mitigate greenhouse effects by carbon sequestration. Temperate fruits can contribute to the horticulture industry by providing a wider option of choice and access in the face of ever increasing domestic demand for fruits. Temperate fruits that can suitably grow in Ethiopia are grouped under two categories depending on their requirements for low temperatures, low- and medium- chill. Over the past years, temperate fruits have emerged as one of the potential horticultural crops in accelerating economic growth. The SNNP, Oromia, Amhara, and Tigray Regions are the major producers of temperate fruits, particularly of apple, peach, plum, pear and strawberry. Propagation of planting material has become an important business in Chencha (SNNPR), Degem (Oromia), Agena (Tigray) and Kosober (Amhara) areas whilst the area under apple production is expanding at a faster rate and produces are often destined to Addis Ababa or larger cities in their environs. Owing to the combined effects of successful apple seedling business, increased demand for apples in local and national markets and the collective efforts of various stakeholders, investment in apple production has become an attractive venture in the highlands of Ethiopia.

Nutritionally temperate fruits are: very nourishing, aromatic and delicious and thus are considered healthy as they are rich in vitamins, calcium, phosphorus, potassium and organic acids; not to mention their veritable potency in preventing a host of pathological ailments and disorders. Therefore, like most edible horticultural crops, today temperate fruits constitute part of the rapidly growing league of new food stuffs relished by ordinary households in Ethiopia. Although their present state of processing is yet rudimentary, they can potentially be processed into versatile products such as concentrated fruit juice; sauce; slices; chips; vinegar; 'pop wine'; cider; various canned and dried fruit products; and ingredients of cakes, pies and pastries.

Fruit trees can also play a significant role in conserving natural ecosystems through: reducing soil erosion and nutrient leaching; bring nutrients up from deeper soil layers to the upper and thus increase their redistribution in the root zone; serve as a possible conduit for groundwater cleanup and recharge; and carbon sequestration for mitigation of greenhouse effects. Fruit trees can also serve as contour hedge rows in areas of high slope to encumber forces eroding soil. Integrating fruit crops in farm and rangelands can increase total productivity, reduce sensitivity to short-term fluctuations by spreading risk through species diversity and increase overall system sustainability.

Situation Analysis

Two categories of forces and factors influencing the conception, formulation, action and implementation of the strategy were analyzed as external and internal factors. The external factors (influences that are outside the research system) represent both the interests of stakeholders that the research should serve and the potential role that they can play to complement or synergize the research. Specific situations or stakeholders' interests that hold back research stride or the research falls short to positively respond to, represent the challenges (C); while those that create motivation for the research represent the opportunities (O). Therefore, the situation analysis of the external factors essentially examined Opportunities and Challenges (OC) presented from the existing Political /Policy /Legal, Economic, Educational, Socio-cultural, Technological/ Technical, and Environmental (PEST) perspectives of the factors. Almost all key stakeholders, notably the Ministries of: Agriculture and Natural Resources, Trade and Industries; exporters; private industries; farmers' unions; various relevant technical units of EIAR; the Regional Research Institutes and centers; and Higher Learning Institutions involved in Temperate Fruit Crops research have taken part in the process.

Analysis of the internal situation (influences that are outside the research system) was made by scrupulously examining whether or not there exists the capacity within the research system that can readily be deployed by the team to deliver outputs or promptly respond to stakeholders' quests or challenges. While the presence of such a capacity denotes the strength (S) of the team; the capacity which is required to deliver desirable outputs but falls short to exist represents the weakness (W). Therefore, analysis of the situation of internal factors examined Strengths and Weaknesses (SW) of the research team in terms of the existing resources (human, physical and fiscal); inter- and intra-disciplinary integrations, complementarities and synergies; availability of technologies, information and knowledge; and organization of internal system, and geographic coverage of the research program.

The results from the situation analysis were finally consolidated in a form of metrix whereby prevailing strengths, weaknesses, opportunities, and challenges (SWOC) were narrated with respect to their relevance to the various thematic areas that the research team is engaged in. From the situations narrated as such then were formulated the issues that the research system needs to address in the short-, medium-, and long- term plans. Experiences of other countries with respect to the level they have reached in research and development aspects of temperate fruit crops were also examined to set a benchmark for the strategy.

Issues, Themes and Strategic Interventions

The major strategic thematic areas identified for the Temperate Fruit Crops Research Program include: Genetics and breeding; Crop protection; Agronomy and physiology;

Irrigation water and nutrient management; Food science, postharvest management and value addition; Agricultural mechanization; GIS and agro-meteorology; Technology multiplication and seed research; Agricultural economics; Agricultural research extension and gender; Capacity building; and Additional cross-cutting themes.

Most of the research issues identified to be addressed by the temperate fruit crops research team are multi-institutional, multi-thematic, multidisciplinary, participatory, and need to be implemented in collaboration with farmers, extensionists and a wide range of other partners to be involved in the whole spectrum of the value chains. The research themes are built on the disciplinary as well as crosscutting themes briefly discussed hereunder. The strategic interventions proposed to tackle each of the issues identified for each theme, and need to be implemented during the next fifteen years on the: short-, medium- and long- term basis are presented in Table1 following the narrations of the disciplinary and cross-cutting thematic areas.

Research Themes

Genetics and breeding

In the years ahead, the Temperate Fruit crops sub-sector foresees a steady demand for varieties with higher and more stable yields and acceptable quality. To keep pace with this demand, much of the focus will be on developing new varieties that are high yielding, adapted to a variety of environments, and resilient in the face of multiple stresses such as climate change, emergence of new pests and diseases, and other biotic and a biotic factors. The strategy will generally seek to accelerate crop improvement by using both conventional and modern methods and technologies that make possible handling of large volumes of genetic material and select with greater precision. This will involve stronger integration of conventional plant breeding approaches with modern tools and methods of biotechnology.

Crop protection

To make crop production more eco-efficient is to achieve yield stability and reduce the chances of crop failure due to diseases and other pests, whose dynamics are shifting as a result of climate change. To this end, the research will focus on both host plant resistance and biological control with greater emphasis to integrated approaches of controlling diseases, insect pests, weeds and vertebrate pests through Integrated Pest Management (IPM) systems.

Agronomy and physiology

Keeping the principle of eco-efficiency, the agronomy and crop physiology endeavor will focus towards developing improved crop and soil management practices that open the way for optimal expression of genetic potential of varieties and enhancing the physiological and agronomic efficiency of temperate fruit crops.

Irrigation water and nutrient management

Development of water-efficient management practices including micro-irrigation, fertigation; irrigation scheduling, etc. constitute arears of intervention related to production of temperate fruit crops as they form integral components of league of crops that are best fitting for production of high-value crops under irrigation conditions.

Food science, postharvest management and value addition

The temperate fruit crops have a great deal of potential in the food industry. It is therefore, essential to work on chemical characterization and profiling of the available varietes and eventually the genepool for nutritional as well as industrial values. It is also critical to develop recommendations on post-harvest technologies that would improve the shelf life of the crops. Establishing alternative ways of processing the produce in view of increasing their shelf life will also open up a new vista of value addition and product diversification and thus better market opportunities for producers and options of choices for consumers.

Agricultural mechanization

The main challenges associated with agricultural machinery and post-harvest handling is the fact that producers in Ethiopia had little opportunity to employ small-scale farm implements, water pumps for irrigation, means of transportation, and storage structures that are appropriate for temperate fruits. Both pre- and post- harvest operations are done manually and losses in both quantities and qualities associated with manual practices are often appalling. It is therefore, imperative to consider this field of research in this research strategy.

GIS and agro-meteorology

In formulating strategic interventions to be harnessed for achieving the objectives stipulated from the outset, it will be given due attention to GIS and agro-meteorology for better understanding of the dimensions of local climate and farming systems (physical climate, social, economic, farming systems,.) for targeting and developing the right technology for the right environment.

Technology multiplication and seed research

The core of research activities envisioned by the technology multiplication and seed research component of the strategy will be to: identify key problems associated with producing sufficient quantity and quality of initial material by generating basic information that would help to develop technologies addressing the challenges; adopt advanced tools of Tissue culture for developing disease-free planting material of temperate fruit crops; identify and adopt good practices of technology multiplication for large-scale production of the crops; and devising an internal system whereby expeditious multiplication of high-quality planting material would be effected in order to meet ever growing demand.

Agricultural economics

Agricultural economics is among the core themes of research as it plays a vanguard role in linking the biological sphere of the research and the economic validity of the results when actually being implemented by the farmer or other targets in the recommendation domains. Furthermore, it has also a key role to play in addressing policy issues that are instrumental in developing and promoting efficient, functional and sustainable value chains of the temperate fruit crop commodities.

Agricultural extension and gender

The agricultural extension and gender component of the research brings in stakeholders together to formulate relevant research agenda as it does also take out promising research results to the demonstration and extension processes. Notwithstanding the role the extension component plays in addressing the social aspects of the research, it is the main channel for the two-way flow of information between the research system on one hand and the end users of the research results on the other. Therefore, addressing issues related to socio-economic and research extension in the strategy is vital to attain the successes that the research team envisages. It will also be crucial to address issues related to gender equality and inclusiveness of the research process in general through this component.

Capacity building

Two important issues were identified under this topic: (i) the need for strengthening the capacity of the research team; and (ii) the stakeholders involved in the temperate fruit crops value chains in general need to have a strong, functional, influential and sustainable forum that will shape up the future of the research, production, processing, trade, and consumption of the commodities.

Crosscutting themes

Gender: The role of women in the agricultural system is critical as women contribute 70 percent of farm labour at harvesting and in post-harvest activities. But women farmers have only limited access to resources, services, land and credit. Unequal gender relations often make women more vulnerable to the effects of poverty, land degradation, and climate change. If the gender gap were eliminated, FAO asserts that total agricultural output would increase. Cognizant of this, the strategy upholds integration of gender concerns into research objectives, technology development, extension, and evaluation frameworks.

Climate change: In Ethiopia, climate change is already having an impact on the livelihoods of different communities in different corners of the country. Therefore, the research strategy will place due considerations to availing technologies that would help actors in the value chains of temperate fruit crops to respond to climate change through adaptation and/or mitigation approaches.

Knowledge management (KM): Through KM interventions aided by new

information technologies, it is possible to help improve smallholders' access to resources that help them improve their farm productivity and competitive ability. KM will also help to create research products in a more collaborative manner that makes them more suitable for diverse audiences. For this purpose, the research team will make results more readily available, spearhead formations of multi-stakeholder platforms that facilitate interaction and promote learning for change, mentoring, and networking.

Strategic Interventions and Expected Outputs

Table 1 Strategic interventions planned to address critical issues facing the National Temperate Fruit Crops Research Program in the short-, medium-and long-term

Thematic areas	Strategic Interventions		
	Short term (5 years)	**Medium term (10 years)**	**Long term (15 years)**
5.2.1 Genetics and breeding			
Narrow genetic base, limited germplasm source, little/no basic genetic information for traits of interest (e.g. gene action and inheritance of traits); negligible breeding work; little/no application of modern biotech tools; and no system of germplasm maintenance	• Introduce new germplasm materials of temperate fruits with low-chill requirements and develop scion- and rootstock- varieties with desirable traits; • Establish internal quarantine system to control foreign pests; • Take inventory of materials of temperate fruits introduced, collected, screened and evaluated in the country; • Establish basic genetic information on traits of interest (e.g. gene actions and inheritance of traits) for future use in variety development; • Prepare electronic and print (in the form of a booklet) registries of adapted or elite clones of temperate fruits as part of a data base for public use; • Study the flower biology of representative stocks of temperate fruits; and establish crossing blocks with clones/varieties containing desirable traits;	• Introduce new germplasm materials of temperate fruits with low-chill requirements and develop scion- and rootstock- varieties with desirable traits; • Screen and evaluate new collections and introductions; • Establish basic genetic information on traits of interest (e.g. gene actions and inheritance of traits) for future use in variety development; • Use biotechnological tools for enhancement of germplasm including the use of somaclonal variation in creating genetic variability; • Update and expand the data base on the registry of adapted or elite clones in easy-to-use formats that can be widely accessed • Widen genetic variability through intentional-crossings of individuals that can ostensibly result in populations from which selection of superior types could be made; • Develop and test *in-vitr*o MAS breeding for yield, desirable quality traits and stress tolerance; and test, *in-vivo,* the clones generated in this manner to verify conformity of the methods for the traits	• Press forward aggressively enhancement of germplasm using both conventional and biotechnological tools such as gene mapping and bioinformatics; • Identifying new sources of scion and rootstock varieties with desirable traits; • Establish basic genetic information on traits of interest (e.g. gene actions and inheritance of traits) for future use in variety development; • Update and expand the data base on the registry of adapted or elite clones in easy-to-use formats that can be widely accessed; • Widen genetic variability through intentional-crossings of individuals that can ostensibly result in populations from which selection of superior types could be made; • Develop and generate clones and varieties with desirable traits of yield, quality and stress; • Characterize and study genetic variations of the crops using biotechnological tools;

	• Initiate capacity building on research topics of MAS, *in-vitro* breeding and maintenance techniques and tissue culture; • Maintain and conserve adapted and elite clones of temperate fruits and • Compile morphological descriptors for collected rootstock varieties.	under question; • Characterize and study genetic variations of the crops using biotechnological tools; • Optimize biotechnological protocols and procedures for hard-to-root species and • Develop *in-vitro* protocols for conservation of clones of selected fruit crops.	• Optimize biotech protocols and procedures for crops not yet done; • Study the molecular bases of chilling-requirements in different apple cultivars and • Start application of *in-vitro* techniques for conserving elite varieties and clones of fruits.
5.2.2 Crop protection			
Inadequate knowledge and skill on prevalence, phenology, population dynamics and ecology of economically important pests; insufficient IPM approaches; and inadequate use of molecular diagnostic techniques and management practices against economically important pests	• Establish basic data on identification and distribution of major and potential pests (insect pests - wooly aphids, rosy leaf-curling aphid; diseases - alternaria leaf spot, apple scab, powdery mildew, and apple canker; and weeds) of temperate fruits in all production areas and potential agro-ecologies; • Study the biology, epidemiology, race/biotypes and dynamics of major diseases of temperate fruits; • Introduce and test IPM-compatible agrochemicals, biological pesticides and botanicals against major pests of fruits and • Assess and document knowledge and biological control agents of major pests (insect pests, diseases and weeds) of temperate fruits.	• Study the phenology of major pests; and biology, epidemiology, race/biotypes and dynamics of major diseases; • Develop disease indexing; • Develop and register appropriate management/control methods/measures for the major pests (insect pests, diseases and weeds) of temperate fruits; • Develop botanicals for major insects and diseases and • Identify genes for disease resistance using molecular approaches.	• Study population dynamics and ecology of major pests of temperate fruits; • Develop effective integrated disease management (IDM) methods against major diseases; • Develop new and more effective botanicals against major postharvest diseases; • Identify disease resistance genes using molecular approaches and • Study inheritance of the resistance genes and transfer them onto established varieties.

5.2.3 Agronomy and physiology			
Agronomic and nutrient management practices that are specific to growing AEZs; crop load management practices; and eco-physiological and dormancy dynamic responses of temperate fruits to different AEZs	• Establish planting systems and population densities appropriate for the different temperate fruits and growing environments; • Establish nutrient requirements, soil-test-based fertilizer rates and application methods and time for temperate fruits in different AEZs; • Identify suitable seed stratification methods for peach; • Determine rootstock population density for production of good-quality seedlings of different temperate fruits and • Establish appropriate canopy management practices and standardize the flower and fruit management and • Generate preliminary information on eco-physiological relations and responses of fruit varieties with various categories of chilling requirements and ecological niches.	• Establish appropriate planting systems and population densities suitable for multiple cropping such as intercropping, strip cropping; • Establish nutrient requirements, soil-test-based fertilizer rates and application methods and time for new crops and varieties of temperate fruits and AEZs; • Develop integrated soil fertility management practices; • Establish appropriate canopy management practices and standardize the flower and fruit management for new crops and varieties of temperate fruits and AEZs and • Identify determinants of yield and impact of temperature to induce growth cessation and dormancy.	• Establish appropriate planting systems and population densities of new crops and varieties suitable for multiple cropping such as intercropping, strip cropping, • Establish nutrient requirements, soil-test-based fertilizer rates and application methods and time for new crops and varieties of temperate fruits and AEZs • Refine canopy management practices and standardize the flower and fruit management for new crops and varieties of temperate fruits and AEZs.
5.2.4 Irrigation water and nutrient management			
Crop water requirement, irrigation scheduling, efficient irrigation systems, and fertigation	• Determine crop-water requirements and irrigation scheduling (frequency, quantity, and timing of irrigation) to optimize crop growth and productivity of temperate fruits; • Establish effective and water-	• Determine crop-water requirements and irrigation scheduling (frequency, quantity, and timing of irrigation) to optimize crop growth and productivity of new crops and varieties of temperate fruits; • Identify critical growth stages to be synchronized with availability of irrigation	• Determine crop-water requirements and irrigation scheduling (frequency, quantity, and timing of irrigation) to optimize crop growth and productivity of new crops and varieties of temperate fruits; • Develop water-use models capturing

	efficient irrigation systems such as drip irrigation with a double purpose of watering in conjunction with application of fertilizer (fertigation).	water and • Undertake elaborated studies on fertigation.	variables of crop and environmental factors for optimum irrigation scheduling in orchards.
5.2.5 Food science, postharvest management and value addition			
Postharvest losses and management technologies; physicochemical quality determination; and value addition	• Determine extents of postharvest losses of major temperate fruits and develop appropriate packing material for fresh market and processing of produce; • Develop/adopt standards and fruit quality test procedures for temperate fruits and products; • Determine the physicochemical quality profiles of fresh fruit and semi-processed products of adapted temperate fruit varieties; • Identify and develop value added products (table fruits; juice; cider - *an alcoholic beverage made from the fermented juice of fruits*; piesand • Study the influences of varieties and environment on the quality of temperate fruits and processed products.	• Develop recipes for different products of the temperate fruits; • Establish appropriate mashing and fermentation conditions for temperate fruits to be used as raw material for cider and other fermented products; • Determine the physicochemical quality profiles of fresh fruit and semi-processed products of widely-grown varieties and elite materials on pipeline; • Undertake studies on the influences of genotypes and environment on the quality profile of fresh and processed products of temperate fruits and • Fine tune and promote value addition in alternative products of temperate fruits (juice; cider; pies; flour; sloes- *small, sour, blackish fruit used for flavoring;* and the likes).	• Refine and promote results and achievements from preservation and postharvest studies; • Develop modified atmospheric storage and ethylene management; • Expand determination of the physicochemical quality profiles of fresh fruit and semi-processed products of temperate fruits and • Refine and promote alternative value addition and product development in .temperate fruits
5.2.6 Agricultural mechanization			
Small scale harvesting, handling, packing and processing technologies	• Inventorize, evaluate and adopt existing and potential pre- and post-harvest mechanization technologies suitable for temperate fruits	• Avail pre- and post-harvest mechanization technologies through adaptation to suit existing situations	• Adapt state of the art technologies appropriate for production and processing of temperate fruits that can leverage the country to benefit from its competitive advantage of proximity to

			potential export markets
5.2.7 GIS and agro-meteorology			
Lack of information on spatial suitability analyses, climate characterization and modeling, and adaptation responses to curb risks associated with climate change on temperate fruits	• Undertake spatial suitability analyses and mapping of temperate fruits under various AEZs; • Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall in meeting crop water requirements under rain-fed system across AEZs.	• Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall and water requirements under irrigated agriculture; • Develop integrated management practices fostering crop adaptation to increased heat load in temperate fruit plantations.	• Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall and water requirements under irrigated agriculture; • Develop integrated management practices fostering crop adaptation to increased heat load in temperate fruit plantations.
5.2.8 Technology multiplication and seed research			
Quality control standard and system for seedling multiplication; and poor linkage with stakeholders; and insufficient availability of improved clones or varieties	• Optimize nursery management packages for production of high-quality and quantity seedlings of temperate fruits; • Prepare seedling production manuals and guidelines for major temperate fruits; • Establish internal quality control system and standards for multiplication of good-quality seedlings of temperate fruits and • Establish application of plant tissue culture and micro-propagation techniques for mass production of good-quality planting material of temperate fruits.	• Develop, through multidisciplinary approach, improved pre- and post- nursery handling and management practices and techniques for production of good-quality rootstock and grafted-seedlings; • Strengthen internal quality control system and standards for multiplication of good-quality seedlings of temperate fruits and • Expand application of plant tissue culture and micro-propagation techniques for both mass production of good-quality planting material and maintenance of temperate fruits.	• Determine standards of both physical (length, stem diameter and vigor) and health (freedom from pests) parameters of rootstock-quality seedlings for different genotypes and environments; • Enhance participation of farmers, private sector and community organizations in production and multiplication of good-quality planting material and seedling of both rootstock and grafted-seedlings and • Expand application of plant tissue culture and micro-propagation techniques for both mass production of good-quality planting material and maintenance of temperate fruits.
5.2.9 Agricultural economics			
Limited information on value chains of temperate fruits; and Lack of studies on	• Map the value chain actors and stakeholders of the various	• Update the work on mapping the value chain actors and stakeholders of the	• Update the work on mapping the value chain actors and stakeholders of the

basic information of temperate fruits	temperate fruits and determine market efficiencies; • Develop viable business models for multiplication and marketing of fruit seedlings and • Determine the production economics (cost, revenue and profit analysis) and investment opportunities for production of temperate fruits.	various temperate fruits and determine market efficiencies; • Generate basic information and knowledge on the status of adoption, diffusion and impact of temperate fruit technologies and • Update the production economics (cost, revenue and profit analysis) and investment opportunities for production of temperate fruits fits.	various temperate fruits and determine market efficiencies; • Update the basic information and knowledge on the status of adoption, diffusion and impact of temperate fruit technologies; • Update the production economics (cost, revenue and profit analysis) and investment opportunities for production of temperate fruits fits.
5.2.10 Agricultural extension and gender			
Inadequate methods of promotion and popularization of fruit production and consumption in urban and rural areas; and limited stance of gender mainstreaming in production, marketing and utilization of fruits	• Strengthen research-extension-farmers linkages and participatory research; • Enhance community-based seedling multiplication schemes (cooperatives, fruit-grower groups); • Enhance production and distribution of good-quality seedlings of temperate fruits through increased participations of farmers and community-organizations in nursery establishment and seedling production and • Characterize and mainstream gender roles and perspectives in the value chains of temperate fruits.	• Strengthen and also develop new models of production and distribution of good-quality seedlings of temperate fruits through increased participations of farmers and community-organizations in nursery establishment and seedling production; • Strengthen the process of mainstreaming and role of gender in the value chains of temperate fruits.	• Strengthen and also develop new models of production and distribution of good-quality seedlings of temperate fruits through increased participations of farmers and community-organizations in nursery establishment and seedling production; • Strengthen the process of mainstreaming and role of gender in the value chains of temperate fruits.
5.2.11 Capacity building			
Skilled human resources in modern tools for crop improvement and quality	• Provide short-term trainings on modern tools of plant breeding	• Provide trainings raising skills or specializations of technicians or	• Provide trainings raising skills or specializations of technicians or

analysis; and limited research infrastructure (lab facilities, standard store, greenhouse, nurseries); and poor linkage of research system with other stakeholders along the value chain	and utilization of modern equipment for analysis; • Establish standard greenhouse and avail some basic biotechnological lab materials (Laminal hood, Gel electrophoresis and PCR, etc.) and equipment for quality analysis; • Capacitate selected fruit nurseries in the potential regions for multiplication of seedlings of adapted varieties and • Establish temperate fruit stakeholders' platform.	researchers in modern tools for crop improvement and quality analysis ; • Modernize the lab facilities to attain state of the art of biotechnological and quality analyses and • Strengthen the platforms established for promoting development of the temperate fruits sub-sector.	researchers in modern tools for crop improvement and quality analysis; • Modernize the lab facilities to attain state of the art of biotechnological and quality analyses; • Strengthen the platforms established for promoting development of the temperate fruits sub-sector nationally and forge international networking.
5.2.12 Crosscutting themes			
Gender	Organize gender disaggregated data for technology dissemination, adoption and impact of technologies; and in the course of technology demonstration, popularization, and training ensure that all female-headed households and at least 30% of beneficiaries to be women from male-headed households		
Climate change	Develop research programs that would adequately address the challenge to increase resilience of vulnerable communities		
Knowledge management	Consider modern facilities of ICT instrument in knowledge and information transfer and sharing processes		

The Next Steps

Following the approval of the strategy document by the top management of EIAR, it is essential to prepare the implementation plan, without which this strategy is not going to reach fruition. The implementation plan document will be developed using a common Guideline adopted by the EIAR Planning, Monitoring and Evaluation Directorate to provide guidance to research teams develop implementation plans. The implementation plan will thus come out as Volume II of the research strategy, which will serve as the blueprint to guide the National Temperate Fruit Crops Research for the next fifteen years (2016-2030). The major contents of the implementation plan will revolve, among others, around the following topics:

- Develop implementation plan;
- Develop monitoring and evaluation plan;
- Develop impact assessment plan and
- Develop reassessment plan for the strategy.

Tropical Fruits Research Strategy

Introduction

The fruit crops Banana, Papaya, Pineapple, Passion fruit, Date palm, and Cactus pear which are grown mainly in the hotter climates of the lowlands constitute EIAR's Tropical Fruit crops Research Program. Ethiopia is endowed with agro-ecologies favorable to grow these crops; and more than 38 fruit species are currently under various levels of cultivation in Ethiopia. Nowadays, fruits are becoming important crops in Ethiopia as the number of small-holder fruit producers has been increasing at an average rate of 12% per year over the last half a decade or so and currently ca. 3.6 million households are producing fruits on average plot sizes of $120m^2$. The majority of producers and production land are linked with tropical fruits. Annually 43,500 ha of land is devoted to fruit production and a total of 261,000 metric tons is produced from which less than 2% is exported. The size of land and volume of production logged under fruits clearly represent only a diminutive proportion of the potential that the country could reap from this important sub-sector as a consequence of multiples of interactive factors hindering its expansion.

In pursuit to reverse the dire situation of the horticulture sub-sector in general and that of the fruits in particular, the Government of Ethiopia has taken a number of measures that would embolden the industry. Fundamental among these bold measures is the establishment of the Ethiopian Horticulture Development Agency (EHDA). The government has also introduced attractive packages of incentives for both local and foreign investors engaged in horticultural ventures. These include such privileges as: provision of loans up to 70 percent of the investment capital; duty-free import of farm implements and equipment; and a five-year tax holiday to export-oriented growers. The government has also set a target of increasing production of fruits and vegetables from 1.28 million tons to 5.91 million tons by doubling the average productivity from 84 to 165 quintals per hectare and expanding land from 152.6 to 236 thousand hectares during the Second Growth and Transformation Plan (GTP II) period.

In order to achieve this ambitious plan, it is critical that two conditions must be fulfilled instantaneously. First, beside increasing production by the smallholders sector, large- and medium- size orchards producing tropical fruits have to increase substantially. Second both sectors need to be assisted by the research system to get access to improved technologies, agricultural innovation, information and knowledge so that they would be able to produce high- quality and volume of products that are competent in both domestic as well as export markets. For the research system to attune itself with such a vital role of developing the Tropical fruits sub-sector, EIAR has decided to develop this long-term research strategy traversing fifteen years.

The strategy is organized in six major chapters whereby this background section together with descriptions of the rationale, vision, mission, goal and objectives constitute the introductory chapter 1. Chapter 2 provides an overview of the importance of tropical fruit crops in the Ethiopian agriculture; and food and nutrition security. Chapter 3 briefly discusses the situation analysis undertaken by assessing the internal environment as well as the external one involving all the key stakeholders to

capture their reflections, concerns and desires. In chapter 4 are presented the critical issues that have been sifted out from the situation analysis and articulated as key challenges facing the tropical fruit crops research program. Chapter 5 discusses the actual strategic interventions to be pursued under the various thematic areas of the research to tackle the critical issues identified. Chapter 6 provides key elements of follow up documents that need to be worked out in the next steps as they are prerequisites for effective implementation of the strategy.

Rationale

Currently, the tropical fruits industry is not contributing to its level best albeit the potential it can have to: ensure food and nutrition security for millions of small-scale farming households; strengthen the opportunity for job creation and income generation; foster expansion of agro-industries, agri-business and import substitution; diversify the base for foreign earnings; and stabilize the macro-economy in general. Cognizant of its potential, the Government of Ethiopia has put in place favorable policy and regulatory frameworks that can be instrumental to propel the progress of the sub-sector which in turn would benefit small-scale and commercial growers, agro-industries and consumers of tropical fruits.

Therefore, the need for maximizing utilization of potential agro-climatic, physiographic and hydrologic conditions of the country to increase production, productivity and marketability of tropical fruit crops is a matter of urgency. In the present context though not only is wide the gap between what is available at research level and how much of that is being used by the farmer; but also are little the results attained thus far by the research system in comparison with the potential that could be realized from these crops. In order to create a condition where these divergent scenarios could converge and thus the commodities' potential could best be exploited, it is absolutely necessary to develop a well-defined and an all-inclusive research strategy representing and addressing the interests of all the key stakeholders involved in the value chains of the crops. Such a strategy not only creates a stronger cohesion and partnership among stakeholders but also serves as a roadmap to: guide the research program planning and implementation in line with the objectives and targets of GTP-II and that of EIAR; track records of results and lessons; and mobilize resources from national and/or international sources. It is with this rationale that the National Tropical Fruit Crops Research Program (NTFRP) - Team has developed this Research Strategy to achieve a common vision and objectives.

The NTFRP-Team has a strong conviction that a thriving future for the commodities can be achieved only if it involves meaningful collaborations between farmers, input suppliers, exporters, actors in agribusiness and agro-industry, traders, technicians, scientists, and others engaged in the value chains. To this end, the research team has formulated a set of principles and values that reflect its vision, mission, goal and objectives underpinning its commitments and desires as indicated below.

Vision

The vision of the National Tropical Fruits Research Program is to become a leading agricultural program providing technological innovations and knowledge that can significantly contribute to improved livelihoods and environmentally sustainable development

Mission

The mission of the NTFRP is to generate, develop, adapt and promote competitive agricultural technologies, innovations, information and knowledge for improving productivity, nutritional quality and sustainable development of agriculture, agribusiness and agro-industry, supporting attainment of self-reliance and import substitution, and broadening the opportunity to exploit the potential export markets and income generations for households and the country

Goal

The goal of the NTFRP is to contribute to the EIAR's role towards the achievement of the sectorial objectives of ensuring food security; sustainable delivering of raw materials for agro-industries and import substitution; expanding the bases for the country to gain foreign earnings from agricultural exports, and increasing livelihood resiliency and environmental sustainability while reducing vulnerability to climate change

Objectives

The overall objective of the NTFRP is to increase the production, productivity and quality of tropical fruits through multidisciplinary and participatory research approach leading to increased share of tropical fruits in the national economy and advancement by understanding and applying new approaches in the whole set of the industry. Specific objects of the program, among others, include the following:

- To collect, introduce, characterize and develop varieties adaptable to different ecological and agronomic scenarios;
- To develop, adapt and promote improved agronomic and other technological packages suitable for tropical fruits;
- To develop, adapt and promote conventional as well as modern techniques and methods of efficient multiplication of planting material;
- To develop, adapt and promote integrated and sustainable pest (diseases, insects, nematodes, vertebrates and weeds) management packages and
- To develop, adapt and promote appropriate postharvest (maturity indices, harvesting, handling, storage, processing and utilization) management technologies.

Importance of Tropical Fruits

Fruit crops play a significant role in human nutrition, especially as sources of vitamins, minerals, and dietary fiber. For leading a healthy life style, an adult person requires to consume 400 grams of fruits and vegetables per day. However, the actual fruit

consumption in Ethiopia is much far below this threshold; even in the urban areas where consumption of fruits and vegetables is supposedly reckoned to be common, only 1.4-2.3 % of the daily requirement is fulfilled. The fruit industry is relatively new to the agricultural system in Ethiopia and many of the crops have relatively been introduced only recently. More than 500 germplasm accessions of various fruit crops (introduced and locally collected) are under the custody of IBC and different research centers. Of these, banana represents 88 of the accessions, papaya- 115, pineapple- 6, date palm -314 (166 male and 148 female), passion fruit- 6 accessions. Cactus pear naturally exists in a wide range of diversity in the country.

Production of most of the tropical fruits is predominantly concentrated in the south and southwestern parts of the country; whereas production of date palm is currently located in some pocket areas of Afar, Somali, Gambella, Dire dawa, and Benshangul-Gumuz; and that of cactus pear in the north. Passion fruit though is given attention in GTP II, is by and large unknown to the majority of Ethiopians and its production is very limited to a single private company (Africa Juice Tibila S.C.). Hence, industrial processing of the fruit is the best way of making it more valuable both for the local and export markets. Out of the total area of 90,070.83 hectares being cultivated under fruit crops, banana accounts for 60% while papaya and pineapple account for about 3 and 1 percent, respectively. Annually more than 75 thousand tons of fruits are produced in Ethiopia where bananas alone account for ca. 70% of the produce while papaya accounts for 6%. Cactus pear is widely cultivated in Tigray and used for multiple of purposes, human consumption, animal feed, live fencing, bee forage, soil and water conservation, and carmine dye production. The fresh fruits and young *cladodes* (flattened-stem) are also processed into various recipes such as marmalades, jams, candies and mixed products along with other food ingredients. The total area covered by cactus pear in Tigray alone is within the range of 65,000 to 80,000 hectares. It also grows in North Wollo, Afar, Harari, Somali, Dire dawa and Bale; although it's economic value is not yet widely realized.

Fruit and vegetable industries in general have created job opportunities for more than 133 thousand people (70% of whom were female) in 2011/12 indicating the potential that the fruit industry could contribute in offsetting unemployment and poverty reduction in Ethiopia. Although processing of fruits is so far limited to preparation of fresh juice for local markets, private companies like Africa Juice Tibila Share Company have started producing blended concentrates of passion fruit, papaya and mango for export markets in Djibouti, Sudan and Somalia. The potential export markets in United Arab Emirates, United Kingdom, the Netherlands, Belgium, Yemen, Saudi Arabia, and the Russian Federation are immense. However, inadequate production and quality standards are key bottlenecks limiting the development of the industries. More than 8.5 million USD is being spent for the import of processed fruit products and an additional two million USD for importing more than 2.5 thousand tons of dates.

Environmentally, fruit crops have the ability to modify the micro-climate in terms of temperature, relative humidity and wind speed among other things. On farmlands, they

can also improve soil permeability, aggregate stability, water holding capacity and soil temperature regimes. Integrating fruit crops in rangelands can also increase total productivity, reduce sensitivity to short-term fluctuations of climatic conditions, spread ecological risks through species diversity and improve system sustainability. Furthermore, fruit trees can provide alternative land-use options and aid more sustainable farming systems.

Situation Analysis

Two categories of forces and factors influencing the conception, formulation, action and implementation of the strategy were analyzed as external and internal factors. The external factors (influences that are outside the research system) represent both the interests of stakeholders that the research should serve and the potential role that they can play to complement or synergize the research. Specific situations or stakeholders' interests that hold back research stride or the research falls short to positively respond to, represent the challenges (C); while those that create motivation for the research represent the opportunities (O). Therefore, the situation analysis of the external factors essentially examined Opportunities and Challenges (OC) presented from the existing Political /Policy /Legal, Economic, Educational, Socio-cultural, Technological/ Technical, and Environmental (PEST) perspectives of the factors. Almost all key stakeholders, notably the Ministries of: Agriculture and Natural Resources, Trade and Industries; exporters; private industries; farmers' unions; various relevant technical units of EIAR; the Regional Research Institutes and centers; and Higher Learning Institutions involved in Tropical Fruit Crops research have taken part in the process.

Analysis of the internal situation (influences that are outside the research system) was made by scrupulously examining whether or not there is the capacity within the research system that can readily be deployed by the team to deliver outputs or promptly respond to stakeholders' quests or challenges. While the presence of such a capacity denotes the strength (S) of the team; the capacity which is required to deliver desirable outputs but falls short to exist represents the weakness (W). Therefore, analysis of the situation of internal factors examined Strengths and Weaknesses (SW) of the research team in terms of the existing resources (human, physical and fiscal); inter- and intra-disciplinary integrations, complementarities and synergies; availability of technologies, information and knowledge; and organization of internal system, and geographic coverage of the research program.

The results from the situation analysis were finally consolidated in a form of matrix whereby prevailing strengths, weaknesses, opportunities, and challenges (SWOC) were narrated with respect to their relevance to the various thematic areas that the research team is engaged in. From the situations narrated as such then were formulated the issues that the research system needs to address in the short-, medium-, and long- term plans. Experiences of other countries with respect to the level they have reached in research and development aspects of Tropical fruit crops were also examined to set a benchmark for the strategy.

Strategic Issues and Interventions

The major strategic thematic areas identified for the Tropical Fruit Crops Research Program include: Genetics and breeding; Crop protection; Agronomy and physiology; Technology multiplication; Irrigation and water management; Food science, postharvest management and value addition; Agricultural mechanization; Agricultural economics; Agricultural research extension and gender; GIS and Agro-meteorology; Capacity building; and Additional cross-cutting themes.

Most of the research issues identified to be addressed by the Tropical fruit crops research team are multi-institutional, multi-thematic, multidisciplinary, participatory, and need to be implemented in collaboration with farmers, extensionists and a wide range of other partners to be involved in the whole spectrum of the value chains. The research themes are built on the disciplinary as well as crosscutting themes briefly discussed hereunder. The strategic interventions proposed to tackle each of the issues identified for each theme, and need to be implemented during the next fifteen years on the: short-, medium- and long- term basis are presented in Table 1 following the narrations of the disciplinary and cross-cutting thematic areas.

Research Themes

Genetics and breeding

In the years ahead, the Tropical Fruit crops sub-sector foresees a steady demand for varieties with higher and more stable yields and acceptable quality. To keep pace with this demand, much of the focus will be on developing new varieties that are high yielding, adapted to a variety of environments, and resilient in the face of multiple stresses such as climate change, emergence of new pests and diseases, and other biotic and a biotic factors. The strategy will generally seek to accelerate crop improvement by using both conventional and modern methods and technologies that make possible handling of large volumes of genetic material and select with greater precision. This will involve stronger integration of conventional plant breeding approaches with modern tools and methods of biotechnology.

Crop protection

To make crop production more eco-efficient is to achieve yield stability and reduce the chances of crop failure due to diseases and other pests, whose dynamics are shifting as a result of climate change. To this end, the research will focus on both host plant resistance and biological control with greater emphasis to integrated approaches of controlling diseases, insect pests, weeds and vertebrate pests through Integrated Pest Management (IPM) systems.

Agronomy and physiology

Keeping the principle of eco-efficiency, the agronomy and crop physiology endeavor will focus towards developing improved crop and soil management practices that open the way for optimal expression of genetic potential of varieties and enhancing the physiological and agronomic efficiency of Tropical fruit crops.

Technology multiplication and seed research

The core of research activities envisioned by the technology multiplication and seed research component of the strategy will be to: identify key problems associated with producing sufficient quantity and quality of initial material by generating basic information that would help to develop technologies addressing the challenges; adopt advanced tools of Tissue culture for developing disease-free planting material of Tropical fruit crops; identify and adopt good practices of technology multiplication for large-scale production of the crops; and devising an internal system whereby expeditious multiplication of high-quality planting material would be effected in order to meet ever growing demand.

Irrigation water and nutrient management

Development of water-efficient management practices including micro-irrigation, fertigation; irrigation scheduling, etc. constitute arears of intervention related to production of Tropical fruit crops as they form an integral component of league of crops that are best fitting for production of high-value crops under irrigation conditions.

Food science, postharvest management and value addition

The Tropical fruit crops have a great deal of potential in the food industry. It is therefore, essential to work on chemical characterization and profiling of the available varieties and eventually the genepool for nutritional as well as industrial values. It is also critical to develop recommendations on post-harvest technologies that would improve the shelf life of the crops. Establishing alternative ways of processing the produce in view of increasing their shelf life will also open up a new vista of value addition and product diversification and thus better market opportunities for producers and options of choices for consumers.

Agricultural mechanization

The main challenges associated with agricultural machinery and post-harvest handling is the fact that producers in Ethiopia had little opportunity to employ small-scale farm implements, water pumps for irrigation, means of transportation, and storage structures that are appropriate for Tropical fruits. Both pre- and post- harvest operations are done manually and losses in both quantities and qualities associated with manual practices are often appalling. It is therefore, imperative to consider this field of research in this research strategy.

Agricultural economics

Agricultural economics is among the core themes of research as it plays a vanguard role in linking the biological sphere of the research and the economic validity of the results when actually being implemented by the farmer or other targets in the recommendation domains. Furthermore, it has also a key role to play in addressing policy issues that are instrumental in developing and promoting efficient, functional and sustainable value chains of the Tropical fruit crop commodities.

Agricultural extension and gender

The agricultural extension and gender component of the research brings in stakeholders together to formulate relevant research agenda as it does also take out promising research results to the demonstration and extension processes. Notwithstanding the role the extension component plays in addressing the social aspects of the research, it is the main channel for the two-way flow of information between the research system on one hand and the end users of the research results on the other. Therefore, addressing issues related to socio-economic and research extension in the strategy is vital to attain the successes that the research team envisages. It will also be crucial to address issues related to gender equality and inclusiveness of the research process in general through this component.

GIS and agro-meteorology

In formulating strategic interventions to be harnessed for achieving the objectives stipulated from the outset, it will be given due attention to GIS and agro-meteorology for better understanding of the dimensions of local climate and farming systems (physical climate, social, economic, farming systems, etc.) for targeting and developing the right technology for the right environment.

Capacity building

Two important issues were identified under this topic: the need for strengthening the capacity of the research team; and the stakeholders involved in the Tropical fruit crops value chains in general need to have a strong, functional, influential and sustainable forum that will shape up the future of the research, production, processing, trade, and consumption of the commodities.

Crosscutting themes

Gender: The role of women in the agricultural system is critical as women contribute 70 percent of farm labour at harvesting and in post-harvest activities. But women farmers have only limited access to resources, services, land and credit. Unequal gender relations often make women more vulnerable to the effects of poverty, land degradation, and climate change. If the gender gap were eliminated, FAO asserts that total agricultural output would increase. Cognizant of this, the strategy upholds integration of gender concerns into research objectives, technology development, extension, and evaluation frameworks.

Climate change: In Ethiopia, climate change is already having an impact on the livelihoods of different communities in different corners of the country. Therefore, the research strategy will place due considerations to availing technologies that would help actors in the value chains of Tropical fruit crops to respond to climate change through adaptation and/or mitigation approaches.

Knowledge management (KM): Through KM interventions aided by new information technologies, it is possible to help improve smallholders' access to resources that help them improve their farm productivity and competitive ability. KM

will also help to create research products in a more collaborative manner that makes them more suitable for diverse audiences. For this purpose, the research team will make results more readily available, spearhead formations of multi-stakeholder platforms that facilitate interaction and promote learning for change, mentoring, and networking.

Strategic Interventions

Table 1 Strategic interventions planned to address critical issues facing the National Tropical Fruit Crops Research Program in the short-, medium- and long- terms

Thematic areas	Strategic Interventions		
	Short term (5 years)	**Medium term (10 years)**	**Long term (15 years)**
5.2.1 Genetics and breeding			
Limited germplasm and narrow genetic base; sub-optimal quality and productivity; inadequate system of germplasm maintenance; weak integrations and collaborations	• Collect and characterize additional germplasm materials from within the country (date palm, passion fruit and cactus pear); • Introduce additional royalty-free improved germplasm materials from outside sources (banana, papaya, pineapple, date palm, passion fruit and cactus pear); • Introduce additional varieties with desirable traits of yield and quality; • In collaboration with IBC, develop well equipped field gene banks for conservation of indigenous and exotic tropical fruit germplasm across national and regional research centers; • Strengthen integration and joint variety development work with relevant research disciples (crop protection, irrigation, soils, socio-economics, food science and postharvest,)and • Establish partnership with regional research institutions for germplasm exchange/introduction (East African countries).	• Broaden genetic variability (using mutation breeding, hybridization, biotechnological tools,); • Screen and develop varieties that are of good adaptability to different AEZs, fruit yield and quality, and resistance to biotic and abiotic stresses (pests, salinity, heat, cold, drought,.); • Develop varieties with specifically desirable traits such as yield, market/consumer preferences and quality suitability for agro-processing; • In collaboration with IBC, adapt and develop *in-vitro* and cryo-conservation facilities and protocols for different tropical fruit crops; • Strengthen integration and joint variety development work using more advanced techniques and • Establish partnership with international organizations for germplasm exchange/introduction (IITA, BARNESA, Bio diversity, .	• Strengthen activities and approaches of broadening the genetic variability through crossing, mutation-breeding, hybridization and biotechnological tools; • Strengthen development of varieties with specifically desirable traits such as yield, market/consumer preferences and quality suitability for agro-processing; • Strengthen adaption and development of *in-vitro* and cryo-conservation facilities and protocols for different tropical fruit crops and varieties; • Strengthen joint variety development and use of more advanced technological packages with relevant research disciples and • Strengthen the regional and international partnership for germplasm exchange/introduction.
5.2.2 Crop protection			
Limited information on outbreak, biology, epidemiology and ecology of	• Assess and determine major pests (diseases, insects, vertebrates, weeds) of tropical fruits across different AEZs;	• Generate information on molecular and serological disease diagnostic techniques;	• Strengthen generating information on molecular and serological disease diagnostic techniques;

major pests; lack of IPM; limited information on biological/botanical and agro-chemical pest management components; premature decline of orchards and rapid postharvest fruit deterioration	• Generate information on outbreak, epidemiology, biology and ecology of major pests of tropical fruits across different AEZs; • Identify key pests (such as cochineal, bacterial wilt, mealy bug, etc.) and adapt/develop IPM packages and standardize control measures; • Introduce, test and register environment-friendly agrochemicals and biological / botanicals against major pests and • Identify specific causes and develop effective control measures against: crown rot, cigar end rot, black spot, *Fusarium* wilt, mildews, bugs, *Phytophathora*, mites, viruses, nematodes, .	• Develop more advanced IPM packages and standardize control measures; • Develop environment-friendly agrochemicals and biological / botanicals and their application methods against major pests and • Strengthen the development of more advanced and effective pest insect pests, diseases, mites and nematodes) control measures.	• Strengthen the development of more advanced IPM packages and standardizing control measures; • Strengthen the development and use of environment-friendly agrochemicals and biological / botanicals against major pests and • Strengthen the development of more advanced, refined and effective pest control methods.
5.2.3 Agronomy and physiology			
Lack of packages of specific agronomic practices; inadequate technologies for organic products and intensive farming; and knowledge and information on responses to variables of production factors; and limited technologies of tree management	• Adapt and develop appropriate orchard management practices specific for different fruits (passion fruit, cactus pear, etc.) and AEZS; • Develop appropriate nursery management techniques for propagation of healthy and vigorous planting materials (date palm, cactus pear, ; • Adapt and develop appropriate agronomic packages for organic production (INM, bio-fertilizers, cropping systems, etc.) that satisfy niche-market standards; • Adapt and develop appropriate agronomic packages (planting densities, cropping systems, irrigation, fertilization, crop protection, etc.) for intensive commercial orchards; • Identify causes of physiological disorders and develop control measures and • Develop and standardize fruit tree	• Develop more advanced agronomic packages (INM, plant density management, flower and fruit thinning, controlled and hand pollination, pruning and training, sucker management, ; • Develop more advanced agronomic packages for organic and intensive commercial production; • Determine phenological characteristics and their relationships with fruiting seasonality, productivity and quality and • Develop more advanced techniques of fruit tree management.	• Strengthen development of more advanced and refined agronomic packages; • Strengthen development of more advanced agronomic packages for organic and intensive commercial production; • Determine physiological factors causing alternate bearing, flower abscission and fruit drop in cactus pear, date palm, papaya, and passion fruit and • Strengthen development of more advanced and refined techniques of fruit tree management.

	management techniques (sucker management, pollination, flowering fruiting, pruning, training, .		
5.2.4 Technology multiplication and seed research			
Inadequate standards, techniques and protocols; and lack of good-quality initial planting materials	• Adapt and develop standardized conventional and micro-propagation techniques and protocols; • Multiply good-quality initial planting material of tropical fruits using conventional and *in-vitro* mass propagation techniques.	• Multiply good-quality initial planting material of tropical fruits using conventional and *in-vitro* mass propagation techniques	• Strengthen multiplication of good-quality initial planting material of tropical fruits using conventional and *in-vitro* mass propagation techniques
5.2.5 Irrigation water and nutrient management			
Limited irrigation management technologies; and inadequate water-harvesting and saving irrigation /fertigation technologies	• Adapt and develop appropriate technologies for crop specific water requirements and irrigation scheduling across different AEZs; • Develop water-efficient irrigation technologies for different AEZs and • Adapt and develop appropriate water harvesting (seasonal run-off, roof water, etc.) and water-efficient irrigation technologies (drip, sprinkler, pitcher, basin, fertigation, etc.) across research centers.	• Develop more advanced technologies for crop specific water requirements and irrigation scheduling across different AEZs; • Develop and refine more advanced water- harvesting and efficient irrigation technologies for different AEZs.	• Strengthen development of more advanced technologies for crop specific water requirements and irrigation scheduling appropriate for different AEZs; • Strengthen development of more advanced water- harvesting and efficient irrigation technologies for different AEZs.
5.2.6 Food science, postharvest management and value addition			
Limited information on quality standards, nutrient compositions, nutritive values, etc.; and postharvest management technologies	• Assess the causes and determine extent of postharvest losses of tropical fruit crops across different production areas and market outlets; • Adapt and develop improved postharvest management technologies (harvesting, storage, handling, packaging, processing, and • Study the suitability of fruit species and varieties for agro-processing and market/consumer. demands	• Adapt and develop appropriate technologies for value added products; • Refine and develop more advanced postharvest management technologiesand • Establish the conditions dictating suitability of fruit species and varieties for agro-processing and market/consumer demands.	• Develop appropriate crop and product specific (fresh and processed) postharvest management technologies (maturity indices, harvesting, storage, handling, packaging, processing;Refine and develop more advanced postharvest management technologies and • Refine facts established on the conditions dictating suitability of fruit species and varieties for agro-processing and market/consumer demands.

5.2.7 Agricultural mechanization			
Inadequate pre- and post-harvest farm machinery and implements	• Listing research-developed and locally available small-scale technologies, evaluate and promote those appropriate for pre and post-harvest management of tropical fruits; • Adopt and adapt additional state-of-the-art agricultural mechanization technologies appropriate for small-scale farmers growing tropical fruits.	• Avail pre- and post-harvest mechanization technologies through adaptation to suit existing situations.	• Avail more advanced and appropriate pre- and post-harvest implements through adaptation to suit existing situations; • Adapt state-of-the-art technologies of pre- and post-harvest management and avail those which can make the country competent in the world market.
5.2.8 Agricultural economics			
Limited information on value chains; marketing farming systems characterization and diagnostics; and issues of technology adoption and impacts	• Conduct crop-specific analysis of value-chains and determine market efficiencies in different tropical fruit-growing parts of the country; • Develop systems of generating and communicating market information to different actors in the value chains of tropical fruits; • Undertake studies on characterization and diagnosis of farming systems incorporating tropical fruit crops and • Undertake studies on the rate of adoption and impacts of technologies of tropical fruits (bananas, papaya and pineapple).	• Strengthen the study on the dynamics of value chains of selected tropical fruits; • Strengthen the systems developed to generate and communicate market information to different actors in the value chains of tropical fruits; • Strengthen and expand the scope of studies on characterization and diagnosis of farming systems incorporating tropical fruit crops and • Strengthen studies on the rate of adoption and impacts of technologies of tropical fruits (bananas, papaya and pineapple).	• Strengthen the study on the dynamics of value chains of selected tropical fruits; • Strengthen the systems developed to generate and communicate market information to different actors in the value chains of tropical fruits; • Strengthen and expand the scope of studies on characterization and diagnosis of farming systems incorporating tropical fruit crops and • Strengthen studies on the rate of adoption and impacts of technologies of tropical fruits (bananas, papaya and pineapple).
5.2.9 Agricultural extension and gender			
Inadequate promotion and popularization of technologies; inadequate information on participatory technology development, evaluation, and adoption; limited gender mainstreaming in the processes of development and adoption of technologies, and production,	• Create awareness and identify technology-cum-information dissemination and popularization methods enhancing production and consumption of tropical fruits in both rural and urban areas; • Establish a network of platforms serving various interests of stakeholders in major fruit growing areas of the country; • Adapt and disseminate best-bet practices on	• Strengthen methods of awareness creation and technology-cum-information dissemination and popularization enhancing production and consumption of tropical fruits in both rural and urban areas; • Strengthen networks of platforms serving various interests of stakeholders in major fruit growing	• Strengthen methods of awareness creation and technology-cum-information dissemination and popularization enhancing production and consumption of tropical fruits in both rural and urban areas; • Strengthen networks of platforms serving various interests of stakeholders in major fruit growing

marketing and utilization of tropical fruits	successful household-level establishment of cactus pear orchards and cactus moth and cochineal control methods in dryland areas and • Mainstream gender in the processes of development and adoption of technologies; and production, marketing and utilization of tropical fruits.	areas of the country; • Strengthen dissemination of best-bet practices on successful household-level establishment of cactus pear orchards and cactus moth and cochineal control methods in dryland areas and • Strengthen mainstreaming gender in the processes of development and adoption of technologies; and production, marketing and utilization of tropical fruits.	areas of the country; • Strengthen dissemination of best-bet practices on successful household-level establishment of cactus pear orchards and cactus moth and cochineal control methods in dryland areas and • Strengthen mainstreaming gender in the processes of development and adoption of technologies; and production, marketing and utilization of tropical fruits.
5.2.10 GIS and Agro-meteorology			
Lack of information on spatial suitability, climate characterization and modeling and adaptation responses	• Conduct spatial suitability analyses and develop suitability map of tropical fruit crops as distributed across the various AEZs; • Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall in meeting crop water requirements under rain-fed system across AEZs.	• Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall and irrigation water requirements under irrigated conditions; • Develop integrated management practices fostering crop adaptation to increased heat load in tropical fruit plantations.	• Develop modeling tools that can be employed to forecast local climate patterns in terms of seasonality of rainfall and irrigation water requirements under irrigated conditions and • Develop integrated management practices fostering crop adaptation to increased heat load in tropical fruit plantations
5.2.11 Capacity building			
Inadequate resources • Human • Physical • Finance	• Strengthen the number of research and technical staff through recruitment; • Improve technical cunning of the research staff through short- and long-term trainings tailored to upgrade research skills and qualifications; • Strengthen dexterity of researchers and technicians in application of specific topics like *propagation techniques, orchard and postharvest management, molecular breeding, in-vitro conservation, protection,*	• Provide tailored and hands-on short-term trainings on *molecular breeding, in-vitro conservation, postharvest handling, value chain analysis, quality assurance for planting materials, modern technologies of data collection and sharing,* ; • Upgrade the existing and establish additional modern irrigation infrastructure and propagation	• Strengthen medium- and long -term trainings as well as experience-sharing visits on more advanced and up-to-date technologies; • Establish additional research centers and sub-centers across un represented AEZs; • Upgrade the existing and establish modern irrigation infrastructure, green houses and lath houses at the remaining fruit research centers field

	etc. through exposure and experience-sharing visits; • Upgrade the existing and establish additional research laboratories (biotechnology, postharvest and nutrition, soils, plant protection); • Upgrade existing offices, libraries, ICT units, farm machinery, and field vehicles; • Avail necessary field vehicles and farm machinery in each centers implementing research on tropical fruits and • Allocate sufficient budget for research and capacity building and improve efficiency of utilization.	structures (*green houses, shade houses, lath houses, etc*.) at the main centers; • Set up virus-indexing facilities and services across major research centers; • Mobilize additional project grants from resource partners and international research institutions and • Mobilize additional support from national horticultural institutions and large scale commercial fruit farms.	vehicles; and farm machineries for coordinating centers; • Strengthen mobilization of project grants from partners and international research institutions and • Strengthen mobilization of support from and partnership with national horticultural institutions and large scale commercial fruit farms.
5.2.12 crosscutting themes			
Gender	Organize gender disaggregated data for technology dissemination, adoption and impact of technologies; and in the course of technology demonstration, popularization, and training ensure that all female-headed households and at least 30% of beneficiaries to be women from male-headed households		
Climate change	Develop research programs that would adequately address the challenge to increase resilience of vulnerable communities		
Knowledge management	Consider modern facilities of ICT instrument in knowledge and information transfer and sharing processes		

The Next Steps

Following the approval of the strategy document by the top management of EIAR, it is essential to prepare the implementation plan, without which this strategy is not going to reach fruition. The implementation plan document will be developed using a common Guideline adopted by the EIAR Planning, Monitoring and Evaluation Directorate to provide guidance to research teams develop implementation plans. The implementation plan will thus come out as Volume II of the research strategy, which will serve as the blueprint to guide the National Tropical Fruit Crops Research for the next fifteen years (2016-2030). The major contents of the implementation plan will revolve, among others, around the following topics:

- Develop implementation plan;
- Develop monitoring and evaluation plan;
- Develop impact assessment plan and
- Develop reassessment plan for the strategy.

Warm Season Vegetables Research Strategy

Introduction

Ethiopia is endowed with diversified agro-ecological conditions favorable to produce majority of warm season vegetables such as tomatoes (processing, fresh market and cherry), *Capsicums (*hot pepper, sweet pepper and chilli), snap beans, cucurbits, egg plant, amaranths and okra. Smallholder farmers and some commercial farms produce different vegetables in wide altitude ranges (up to 2500 m.a.s.l.) of the country under rain fed and irrigated conditions. The country produces about 852,303.89 metric ton of vegetables from a total of 6,789,289 ha which is 1.43% of the total area covered by all crops at national level (CSA, 2013). Out of the 5.37million ha of potentially irrigable land on which fruits and vegetables could be produced only about 250,000ha of the potentially irrigable land is currently under vegetable cultivation.

Vegetable crops can generally be a very important source of vitamins, minerals and proteins to a country like Ethiopia where the people experience malnutrition due to heavy dependence on cereals. Vegetables primarily contribute to alleviating health problem by providing vitamins, minerals and hence improving the nutritional quality of the Ethiopian diet. Several studies have revealed that vitamin A deficiency is a major public health problem in Ethiopia. Ethiopia can be considered as 'at risk community' country, where less than 75% of pre-school age children consume vitamin A rich foods at least three times a week.

There has been a steady increase in the demand of different vegetable crops for export and processing purposes. Above all, the country is also strategically located for export of fresh produce to neighboring countries like Sudan, Somalia and Djibouti), the Middle East and the EU-markets. Export of fruits and vegetables has been increasing through years from 2002/03 to 2014/15 from 9.6 to 47.5 million USD, respectively)

Currently the horticulture industry in general and warm season vegetable sub-sector in particular is lagging far behind in providing enough nutrition and generating sufficient income from export. Small scale farms, which produce the bulk of vegetables for local consumption, are not in a position to produce vegetables to the standard satisfying the export market. This production practice was characterized by low input, poor water management, high pest and disease damage, high post-harvest losses, poor organization, and uncertain markets.

To date, efforts have been made to improve the production system through availing improved packages of production technologies. In effect, varieties were released and agronomic practices were recommended for major vegetable crops tomato, Alliums and Capsicums. As result, growers have been motivated to the production of these crops. However production, productivity and product quality are still far lower than other countries. Seasonality of production and market problems coupled with high postharvest losses are still major challenges of the sub-sector. On the other hand, limited research focus, lack of knowledge and skill by growers and traditional consumption habit in the country in general have led to restricted production both in quantities and types of vegetable produce. Despite huge potential in producing wide range of vegetable crops

throughout the year, availability and quantity of production is yet dependent on season and limited to certain crop types and area. Availability of packages of technologies for different production systems including irrigated and rain fed in various agro-ecological areas are limited. Due to the abovementioned problems and accompanying under development of the sub-sector, export demand for warm season vegetable crops from the non-agricultural Middle East and some neighboring countries have been fulfilled by imports from as far as the South American countries.

Generally, the sub-sector is unable to meet the existing increasing local demand for vegetables, let alone to compete for export market. During the rainy season, for instance, onion bulb for food is imported from Sudan. Likewise, fresh tomatoes are not available during the rainy season in many areas of the country and supermarkets are full of tomato pastes imported from abroad.

It is clear that with the existing situation, the sub-sector is not able to compete with poor quality products with South America, North Africa and Far East. However, several measures have been taken by the Ethiopian government including investment privileges of provision of 70% of the investment capital, duty-free import of farm equipments and a five year tax holiday to export oriented growers. Consequently, agro-processing companies such as Ethio-vege fru PLC, Ethio-rose PLC, Genesis Farms; etc are producing some high value vegetables for export and local market. Moreover, some flower growers began to diversify the greenhouse vegetables with bell pepper, chilies, tomatoes and snap beans.

The government of Ethiopia has set an ambitious second round five-year growth and transformation plan (GTP II) to bring about transformation in the productivity and production of high value market oriented vegetables. Furthermore, development of climate smart production technologies for sustainable farming and food security are key issues in GTP II.

To improve productivity and volume of production as planned in GTP II, appropriate packages of technologies are required in which the role of research is crucial. While multiplying, promoting and disseminating technologies developed so far, relentless efforts need to be exerted to adapt and develop technologies suitable to address existing challenges as well as emerging issues reflected in GTP II.

In the process, innovative approaches in advancing the benefits of vegetable crops, particularly under the enhanced climate variability and change under the theme climate smart agriculture (CSA) need to take the highest priority. Examples include protected culture, fertigation and organic farming and many more others. The experiences elsewhere in the Far East, North Africa and neighboring countries such as Kenya have shown that protected culture using tunnels and greenhouses have revolutionized horticultural production and resulted in high value products throughout the year. Therefore, developing this sub-sector through building on the efforts made in the past and designing a clear and long term research and development strategy is vital for this country to effectively utilize the different advantages of these crops in the future.

Rationale for the Strategy

With the growing irrigated agriculture and agricultural development led industrialization of the country, there is a very high prospect for the development of the sub-sector as a source of income, nutrition, employment, hard currency earning and raw material for agro-processing industries. In addition to striving to secure self sufficiency in food and nutrition, emphasis in GTP II has been given to market oriented high value warm season vegetables. Local and export demand for vegetable is increasing from time to time. However, there are lots of technological gaps that need to be tackled. Strategic research approach is thus required to support the sub-sector with innovations so as to boast production, productivity and quality of produce. The need for research strategy based on the priority developmental constraints is indispensable in order to increase the contribution of the sub-sector in improving the growers' income and subsequently improve the living standard of the people and contribute to economic growth of the country in a sustainable manner. The strategy will thus serve to guide and coordinate research activities in the next fifteen years facilitating adoption and generation of appropriate technologies, knowledge and information aiming to meet the objectives of agricultural development plan. A strategic research approach is required primarily to:

- Alleviate the existing challenges of warm season vegetable production, productivity and product quality;
- Optimize utilization of available opportunities for vegetable production, utilization , processing and local and export marketing;
- Mitigate adverse effects of climate change and other emerging issues and
- Further developing the sub-sector through technology based production systems of protected culture, drip irrigation and fertigation

Vision

To be a leading program in warm season vegetable technology innovations; availing high quality technologies, information and knowledge that would contribute to economic growth, improved livelihoods and sustainable development.

Mission

Develop, adopt and disseminate vegetable technologies, information and knowledge to increase production, productivity and quality under small scale and commercial production at different AEZs satisfying local and export market, and processing industries

Goal

To increase production, productivity and product quality of warm season vegetable crops under different production systems (irrigated, rain fed, protected and organic farming systems) in both smallholder as well as commercial growers.

Objectives

- Adapt, develop and promote improved technologies, knowledge and information that increase production and productivity and quality of vegetable produce to satisfy the standards of both domestic and international markets

- Coordinate research activities on warm season vegetables being undertaken by various research partners and play key role in building technical capacity of farmers and other stakeholders

Guiding Principles

In order to accomplish its mission and fulfill its objective, the warm season vegetable research program has established a set of guiding principles and criteria for selecting research projects and major activities for the implementation of the strategy. The program will, accordingly, be guided by the following basic and unwavering principles:

- Change in attitudes and perceptions on the part of researchers and support staff;
- Development and expansion of external and internal linkages;
- Team approach and partnership (public and private);
- Loyalty and respect to diverse client needs;
- Responsibility and accountability;
- Environmental consciousness; and
- Inclusiveness(men, women and youth).

Importance of Warm Season Vegetable Crops

Agriculture

Agriculture is the main stay and contributor to the national economy both in terms of income, employment and generation of export revenue and contribution to 44% to GDP has remained very high. Among the sub-sectors of agriculture, crop production is major contributor to GDP accounting for about 28 % in 2012,. Irrigated agriculture has been identified as an important tool to stimulate economic growth and rural development and considered as a cornerstone of food security and poverty reduction in Ethiopia. According to IWMI report (2009) an average income of US$323/ (ha) was generated under smallholder-managed irrigation systems compared to an average income of US$147/ha obtained from rain fed systems which 219.7% higher than the gross margin obtained from rain fed agriculture.

The government of Ethiopia has set GTP II for five years which aims to boost the production of vegetable from 959.54 thousand tones to 2.34 million tones through increasing productivity from 105.6 to 190.8 t/ha. The increase in production is hoped to be achieved through increasing productivity through improved vegetable production technologies and expanding production into the country's 5.37million ha of potentially irrigable land, of which only 250,000 ha is currently cultivated.

Agro-ecology and farming systems

Ethiopia is endowed with favorable agro-ecological conditions to cultivate many of the warm season vegetables crops in the lowlands (<1500 meters above sea level) and midlands (1500-2200 masl). Smallholder farmers and some commercial farms produce different vegetables under rain fed and irrigated conditions. The irrigated vegetable production system is increasing because of increasing commercial farms and development of small scale irrigation schemes.

Major production agro-ecological zones (AEZs)

There are different AEZs with adequate irrigation water, favorable climatic conditions and high potential for the development of the sector.

Hot to worm and low land plains (A1)

This area covers about 30% of the country, which includes some parts of Oromiya, Afar, Somalia administrative regions. It has low rainfall and various soil related constraints. It is generally favorable for production of different irrigated vegetables. It represented by Werer Research Center.

Tepid to cool semi arid and mid high land (SA2)

It is dominated by the rift valley lakes and small streams. It has low rainfall, dry weather and diverse soil related problems. It covers about 0.28% of the country and has high potential for the vegetable industry. Different warm season irrigated vegetables are produced. There are well established irrigated farmers plots, large scale commercial production of diverse mixed vegetables for the local and export market. This agro ecology will be covered by Melkasa Research Center.

Tepid to cool sub-humid mid high land (SH2)

It covers 7.6 % of the country, which includes the mid highland of Southern Ethiopia, which is traditionally a horticulture belt and North Harerge region. Home gardening is a traditional way of providing food for the family in the region. It is represented by Bako, Awassa and Areka Research Centers.

Tepid to cool sub moist mid high land (SM2)

It covers Tigray, Northern and Easter Shewa and North Wollo. It covers wide climatic regions and is about 0.42% of the country. It is represented by Mekelle, Sheno, Debre Zeit and Melkasa Research Centers.

Genetic resource

Diverse and readily accessible genetic resources are vital for any crop improvement program oriented toward high and stable yields and specific consumer preferences then will contribute to food security and a diverse diet for the ever increasing global population. The World Vegetable Center Gene bank maintains the world's largest public vegetable germplasm collection of more than 61,000 accessions from 155 countries, including about 12,000 accessions of indigenous vegetables.

Ethiopia is well known for its diversity of indigenous plants, including vegetables of Ethiopian mustard (Kale), pumpkin, chilli and okra. Okra (Abelmoschus app.) has high diversity in Ethiopia and it is an important vegetable in some parts of the country particularly in the western lowlands (550 to 650 masl) regions. In addition to the cultivated species, the distribution of other two species A. manihot and A. moschatus are reported recently.

On the other hand, poor germplasm base for exotic vegetable crops such as onion, tomato, *capsicums*, snap bean, cucurbitaceous and egg plant and the absence of strong collaboration with international institutions for germplasm exchange have contributed to sluggish development in cultivar development. Since germplasm is the base for cultivar improvement, it is crucial to wisely utilize local genetic resources and also enrich the base through international collaborations and various techniques of variability creation and collection. Numerous economically important vegetables are exotic types and thus research depends mainly on importation of germplasm from different international sources. Thus, there is a need for source of germplasm of these vegetables to improve variety development in the country and compete in the international market. Selection of better parental material in response to challenges of biotic & abiotic stresses and related climate changes are crucial to undertake crossing programs. In addition to devising different strategic options to strengthen international and national collaborations for germplasm exchange, wise exploration of local genetic resources, variability creation via different techniques and technology shopping are therefore priority of priorities.

Production and Productivity

Globally, vegetable production has grown intensively especially on a per capita basis, which has increased 60 percent over the last 20 years. Average vegetable production between 2001 and 2010 was 54 percent higher than the average of the preceding decades (1991-2000). Vegetables cover 1.1 percent of the world's total agricultural area, in which Europe and Central Asia contributing with 12 % of the total global area, and with 14 % of production.

Vegetable production is an important economic activity in Ethiopia, ranging from gardening smallholder farming to commercial private farms. Vegetable crops occupied < 1% and 1.65 % of the total area and production covered by all crops at national level, respectively. A total of more than 0.95 million tones of vegetables were produced from 154,621.3ha hectares creating means of livelihoods for over 8.73 million households. Moreover, vegetable production under commercial farms has also increased from 108.6 thousand tons in 2010 to 221.1 thousand tons in 2015 while productivity and area increased from 34.3 to 35.2 tones and from 9711.2 to 108631ha, respectively, during the same period. The commercial production is concentrated in the rift valley areas of Ethiopia, due to availability of irrigation facility, accessibility and closeness to agro-processing industries.

Warm season vegetable crops of economic importance that largely produced in Ethiopia include Capsicums, onion and tomato and green beans whereas okra, paprika, egg plant and cucumbers have recently emerged as an important export vegetable. Indigenous vegetables such as okra, pumpkin, jute mallow and others are part of the culture of the Ethiopians and contribute to food security and survival to the rural population during adverse drought.

Three major warm season vegetable crops viz. hot pepper, tomato and onion dominate small scale vegetable production in the country with hot pepper (dry and green) occupying 78% and of the total area coverage by the three vegetable crops (126,143.31

ha) followed by onion (18%) and tomato (4%). In terms of volume of production, however, onion occupies the highest share of 49.26 % followed by hot pepper (dry and green) 44.3 % and tomato 6.6%. Although, other warm season vegetable crops such as watermelon, melon, squash, cucumber, pumpkin, okra, egg plant and snap bean are produced as an important export vegetable in the country, the area coverage of these vegetable crops is minimal and often reliable production data are not available.

Total production of tomato, pepper (dry and green) and onion has increased more than two fold with the maximum growth recorded in pepper. The area coverage increments are 133.7, 181.8, 262.9 and 4148% for tomato, dry and green pepper and onion respectively whereas, changes in total production for these vegetable crops is 55.9, 191.6 and 106.5 % respectively between 2004 and 2015.

The total area coverage and production of tomato, dry and green pepper and onion did not show a clear increasing trend; rather oscillated up and down between minimum values of 74860 ha and 379854.8 ton in 2004 and maximum value of 715116.4 ton and 176194 ha in 2012 and 2013 (Figure 1). The increase in production trend of these vegetables in some of the years such as between 2010 and 2012 (Figure 1), however, was attributed mainly due to expansion of irrigated land.

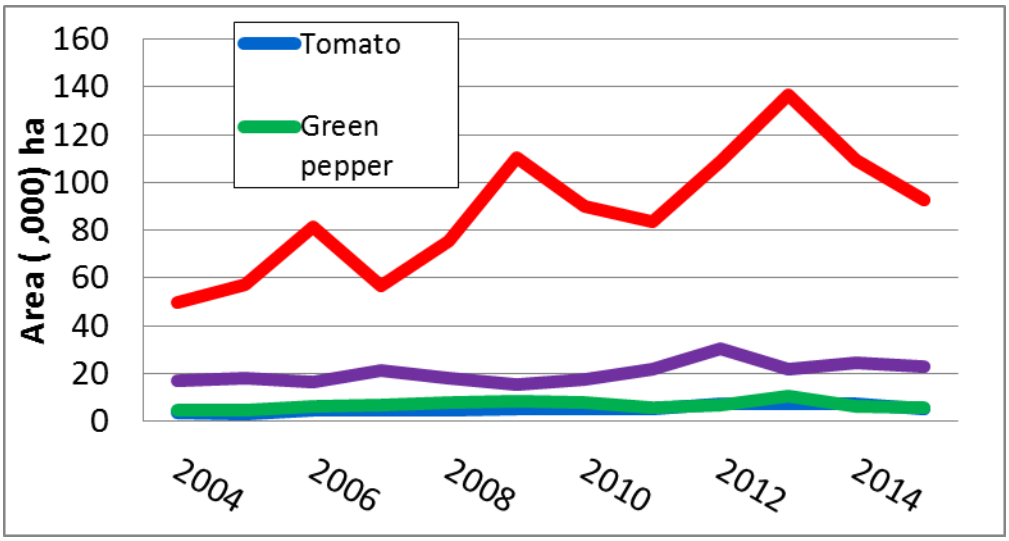


Figure 1: Total area coverage and production of tomato, pepper (dry and green) and onion (Source: CSA, 2004-2015)

The productivity is still lags behind that of major producing countries such as China and India (Table 1) which fails to supply the population with the required income, employment, export, agro-processing and nutrition. Moreover, the national yield of these vegetables failed to attain what can be attained under research managed field; for example the yield gap between maximum national and research managed yields of tomato and onion is more than 200%.

Table 1. Comparison of productivity (t/ha) of major vegetables of Ethiopia with major producers and the World average

Crop	Countries				World average
	Ethiopia	China	India	Kenya	
Onion	10.13	22	16	11.2	19.4
Tomato	6.11	50	20.7	20.5	33.8
Pepper(dry)	1.85	6.8	1.7	1.2	1.8

Food and Nutrition

Vegetables are the major sources of vitamins and minerals, trace elements, dietary fiber, protein and add flavor to diets and provide nutrition to growers and consumers. Although minerals are less bioavailable in plant foods, vegetables provide a large proportion of minerals such as iron and calcium consumed in rural populations in developing countries. Vegetables provide antioxidants such as vitamin A, C and E that are important in neutralizing free radicals (oxidants) known to cause cancer, cataracts, heart disease, hypertension, stroke and diabetes. They are also the most important sources of vitamin A, a nutrient important for several metabolic activities in the body, in addition to its role as antioxidant. Despite the recorded increase in some major vegetables, the production of vegetables is not yet sufficient to adequately supply the population with the required nutrition.

Cognizant of these facts, FAO/WHO recommends 400 gram of fruits and vegetables per day or alternatively five servings a day; at least two servings of fruits and three servings of vegetables (WHO, 2003). However, the daily per capita consumption of vegetables and fruits in Ethiopia has been less than 100g which is less than a quarter of the recommended consumption. Hence, deficiency of vitamins has been the major public health problem in Ethiopia.

Compared to other food group nutrient profiles, vegetables provide the nutrient characteristics that most consumers perceive as health promoting. Vegetables contain no cholesterol, very little fat, sugar, and sodium, yet provides concentrated sources of many vitamins and minerals. Table 3 presents representative nutrient ranges and means for commonly consumed vegetables in Ethiopia.

Table 2. Vegetable Composition based on 100 grams (g) of Edible Material as Raw or Minimally Prepared for Consumption

Vegetable	Water (%)	Energy (kcal)	Protein (g)	Fat (g)	Carbohydrate (g)	Fiber (g)	Ca (mg)	P (mg)	Fe (mg)	Na (mg)	K (mg)
Tomato	94	20.5	1.05	0.2	4.5	1.15	11.5	26	0.4	9	220.5
Onion	89.5	37	1.35	0.15	8.7	2	47	32	0.85	9.5	210
Pepper(hot/chili)	88	40	2	0.2	9.5	1.5	18	46	1.2	7	340
Pepper(sweet)	94	20	0.9	0.2	4.6	1.7	10	20	0.3	3	175
Pumpkin	92	26	1	0.1	6.5	0.5	21	44	0.8	1	340
Squash	91.3	29.2	1.2	0.2	6.9	1.4	24	33.7	0.5	4.5	287.5
Cucumber	95	15	0.7	0.1	3.6	0.5	16	24	0.3	2	147
Melon	90.7	32.7	0.8	0.1	8	0.9	8.7	10.3	0.2	14.3	225.7
Watermelon	92	30	0.6	0.2	7.6	0.4	7	10	0.2	1	112
Eggplant	92	24	1	0.2	5.7	3.4	9	25	0.2	2	230
Mushroom	92	22	3.1	0.3	3.2	1.2	3	85	0.5	4	314
Okra	90	31	2	0.1	7	3.2	81	63	0.8	8	303
Sweet corn	76	86	3.2	1.2	19	2.7	2	89	0.5	15	270

Source: Adapted from USDA *Nutrient Database*

Importance in the National Economy

Food security, income generation and employment

Warm season vegetables are among the most important sub-sectors in the national economy. They are the most popular vegetable crops with versatile food and culinary uses providing micronutrients, fiber, vitamins and minerals essential for a balanced and healthy diet. In addition to supplying energy and building our body, they have been linked to the prevention of or fight against many types of diseases including cancer. Tomato, pepper, onion and other warm season vegetables are used in every Ethiopian house as components of the daily diet. They are used as fresh vegetables and as ingredients of 'Wot', an Ethiopian stew in a daily traditional meal. Despite the importance of vegetables in daily food preparation, consumption per capita is low (Fig. 2). Seasonality of production, perishability, food habit and attack from diseases and insects are among a myriad of factors attributable to low consumption. The sub-sector is labor intensive and plays great role towards creating job opportunities with a particular focus on engaging women, youth and poor households. Vegetable crop cultivation will facilitate additional jobs creation and women involvement in the output marketing and processing. Furthermore, the nature of the crops requires special skill and knowledge.

Warm season vegetables are major sources of cash income for smallholder as well as commercial farmers. When compared with cereals and other crops, vegetables are the most preferred crops for irrigated agriculture because of high productivity and short growing period of vegetables enabling the production of two to three season cycles per year. The return from vegetables per unit area is several folds higher than from major cereals. Market oriented productions using both irrigated and rain fed conditions have been expanding enabling various actor including growers, merchants, consumers,

middlemen, transporters, to take part and benefit in the value chain of this important horticultural venture.

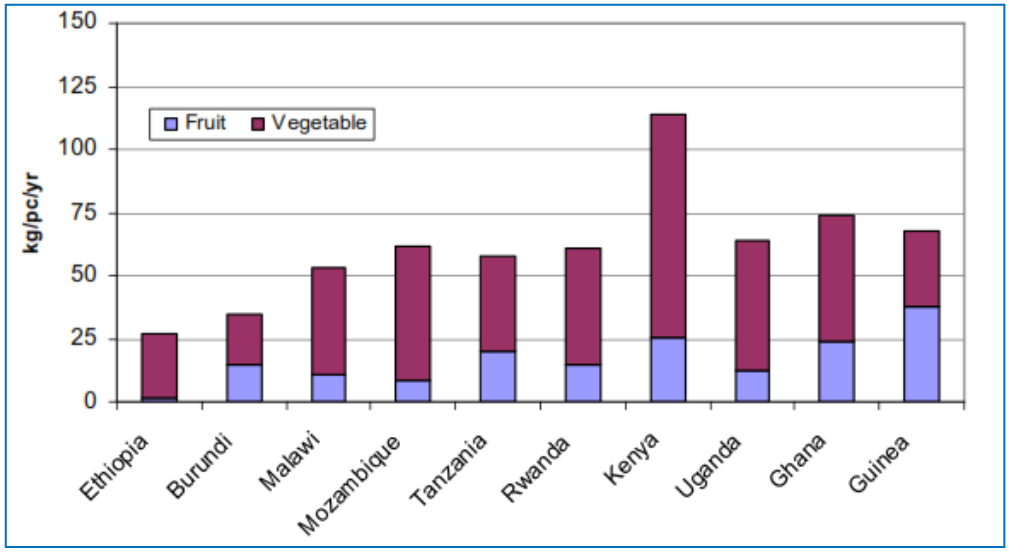


Figure 2. Fruit and vegetable per capita consumption in sub-Saharan Africa
Source: (Marie *et al*., 2004)

Supply of raw material for local agro-industries

Warm season vegetables are used as raw materials for agro-processing industries. Processing of vegetable crops have been given a high priority in the country and as a result access for both local and international markets for processed vegetable products is available (e.g. fresh chilies, frozen vegetables mixed with legume vegetables, tomato paste, tomato concentrate). Currently there are four vegetables processing plants in the country viz Melge Wondo, Gondar, Merti and Green Star food processing factories produce tomato paste and canned vegetables both for local and export markets thus creating job opportunity and generating foreign currency.

Tomatoes are processed and canned as a paste, sauce, ketchup and juice. Paprika oleoresin which is used in a wide assortment of foods, drugs and cosmetics are extracted from peppers. Capsaicin extracted from pepper is also used in the pharmaceutical industry.

Export market and foreign currency earnings

Fresh vegetables have been exported to neighboring African countries (Sudan, Somalia, Djibouti), the Middle East and the EU and generated much foreign currency. The export of fresh and processed (frozen, canned, dried and ground) vegetables has been increasing considerably. In the period between 2010 and 2014 the amount of vegetables exported increased from 51.3 thousand tones to 153.3 thousand tones while the value generated increased from 32.4 million USD to 353.6 million USD (Fig. 3). Somalia, Djibouti and Indonesia are the major importers of Ethiopian vegetables and vegetable products accounting for 68%, 15% and 7% of the export value, respectively (Fig.4). Despite the

promising trend of export and the potential of the sub-sector owing to the proximity of the country to non-agricultural oil producing countries, the sub-sector has yet to improve production, productivity and quality to be able to satisfy local demand and export at competitive price with suppliers from South American countries.

Summary of export of fresh, dried and value added/processed vegetables

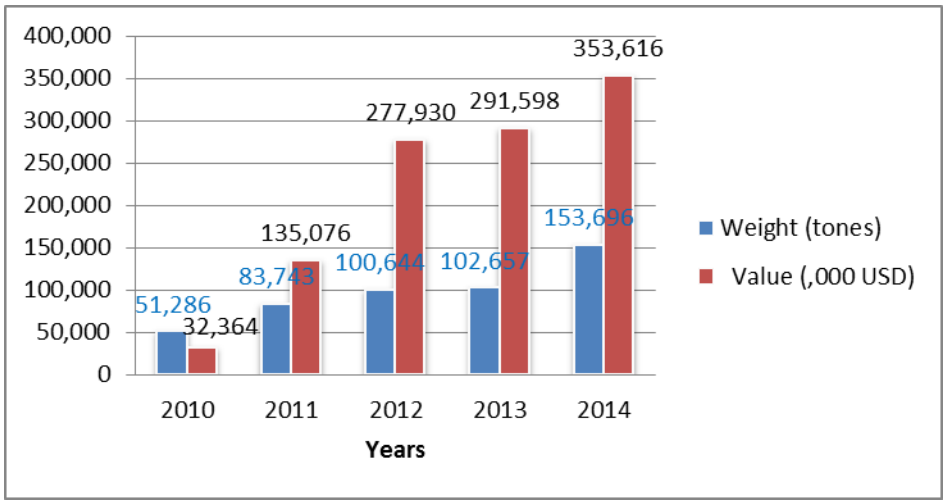
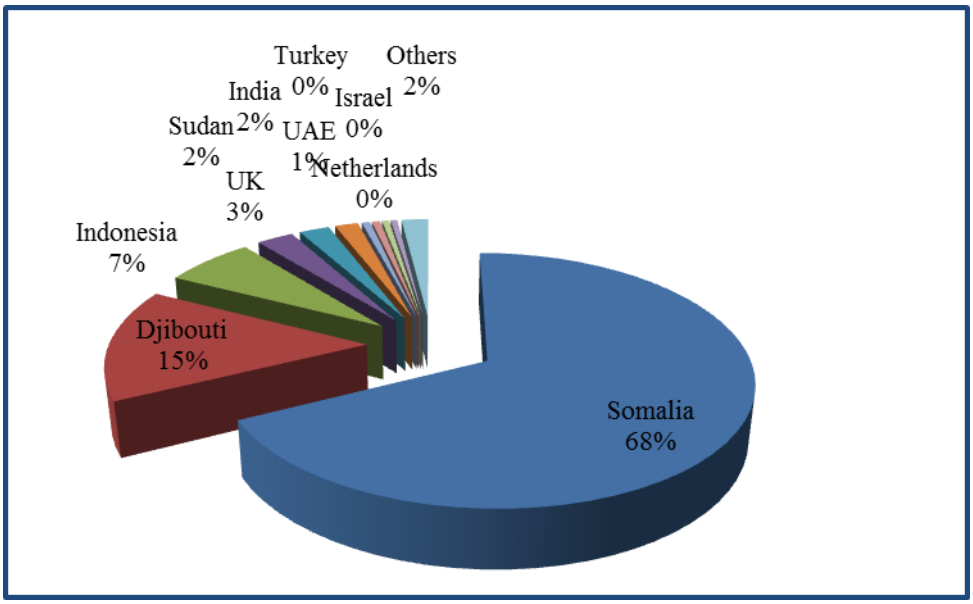


Figure 3 Summary the export value and volumes of fresh, dried and value added/processed vegetables from Ethiopia
Source: www.erca.et.com



Source: www.erca.gov.et
Figure 4. Percent of vegetable export income obtained from different countries

Environmental Sustainability

Properly scheduled and implemented vegetable production system can help to alleviate poverty, provide nutrition security, improve livelihoods, maintain ecosystem and good health, conserve biodiversity, and importantly alleviate greenhouse effects by carbon sequestration. Vegetable are produced throughout the year either rain fed or using irrigation which enable efficient use of land, rotation and increase production.

Assessment of External and Internal Environments

External Environments

The external environment of a program offers important reference points for guiding a research institute. In the external environment, the program finds its greatest reason for existing: its clients, users, beneficiaries, partners and competitors; and the forces that form social, economic, political, technological, and institutional trends. All these imply the emergence of new realities and situations that bring about new demands, challenges, risks, and uncertainties, and new opportunities and threats to the program. Therefore, changes regarding the program should start with analysis of the external environment that affects the program.

The external factors were analyzed using the SWOC (Strength, Weakness, Opportunity and Challenge) framework with additional analytic tools such as PEST+ (Politics, Economics, Socio-cultural, Technologies and Environments/situation).

Political dimension: Assessments were made whether the strategy is aligned with the national, sectoral and institutional policy, strategy and regulatory/legal frameworks and priorities. Since the adoption of the Agricultural Development Led Industrialization (ADLI) by the government, all the policy and strategy frameworks and development programs recognized agriculture to be the engine of Ethiopia's economic growth and development yet exerting relentless strive to promote steady growth of the industrial sector. The current GTP II which provides even greater emphasis to industrialization places utmost priority to those agricultural sub-sectors fostering supply of raw materials for the growing agro-industries and import substitution. Therefore, so many opportunities are set forth by the policy environment to promote research and development of the vegetable crops. As conducive the policy and legal frameworks put in place are, there are also a number of challenges that may surface in due course. Conceivable features of the opportunities to make use of and challenges to be aware of or need to be addressed, from the perspective of the policy dimension, were assessed and sorted out in a matrix of opportunities and challenges presented in Table 4 below.

Economic dimension: The increasingly rising demand of vegetable crops as a result of increasing population and changing lifestyle create the opportunity for the sub-sector to boom. Such an increase in the demand side will trigger famers to increase their outputs. The research has to, therefore, keep pace with the need of the farmers to increase production mainly through increasing productivity and minimizing postharvest losses;

while meeting the demand of the industries for raw materials that are not only sufficient to enable them run in full capacity but also fulfill their requirements of quality standards. The presence of various agro-ecologies and new potential areas to grow vegetables will allow the country to be self-reliant in vegetable; and also for supplying to the potential export markets in neighboring countries and beyond. The number of commercial farms engaged in vegetable production has been increasing which play a great role for supplying high standard vegetable produce and products to regional and international export markets.

Socio-cultural dimension: It essential to clearly understand the opportunities and challenges in order to address or change the perception of the farming society that have been growing warm season vegetable crops and handled as such to be economically, socially, environmentally profitable, viable and sustainable venture. Therefore, the opportunities accruing and challenges emanating from socio-cultural settings around production, processing and trade of warm season vegetables are examined and presented as elements of the SWOC analysis.

Technological dimension: Outstandingly peculiar feature of vegetable crops is the fact that right after production the produce has to be taken to the industries for processing or to the market. Melge Wondo, Gondar, Merti and Green Star food processing factories produce tomato paste and canned vegetables both for local and export markets thus creating job opportunity and generating foreign currency. Clustering and formation of vegetable producing associations which in turn are linked with organized smallholder farmers whereby the two parties enter contractual agreements to supply to the local or exporting markets and to agro-processing industries. This is a good start that should be pursued to engrain value chain approach which in the future will play a key role for the sub-sector to gain momentum.

Environmental dimension: The presence of wide diversity of agro-ecology in Ethiopia favors to grow all kinds of vegetables including seed production. Such divers ecological factors and crop types, provides a fertile ground for a range of pathogens, insect pests, weeds especially parasitic weeds and other menaces to co-evolve with and survive on the crops, against the interest of man. The damages from these biotic factors coupled with climatic and edaphic factors hindering normal growth and development of the crops are among the primary issues that the research team would target to address.

Stakeholder analysis

A list of stakeholders with different roles and demands were examined as these stakeholders play a crucially important role for successful designing and implementation of the strategy and the outputs and impacts thereof. Therefore assessments were made what opportunities the research team could make use of and, by the same token, what challenges it should face up to coming from these stakeholders by merely being involved in providing services of agricultural extension, production, processing, trading and research.

Table 3. Stakeholders/collaborators of the research sector

No	Names of Partners	Role
1	Ministry of Agriculture & Natural Resources	Develop, coordinate and implement national horticultural development strategies and policies, packaging new technologies and dissemination
	Small holders horticulture Directorate	Coordinate implementation and regional ownership in collaboration with the hort. and irrigation offices of Regional BoAs. Take the lead role in organizing joint planning, M&E to align all stakeholders over the sector strategy.
	Small holders Irrigation Directorate	Would contribute in linking producers and consumers.
	Plant health regulatory and quarantine Directorate	Oversee vegetable varieties in use in different agro-ecologies
	Input Supply Corporation Directorate	Facilitate fertilizer and agro chemicals technologies linkage through private distributors and cooperative unions
2	Regional Bureau of Agriculture	Develop, coordinate and implement regional horticultural development strategies and policies, packaging new technologies and dissemination.
3	Higher Learning and Regional Research Institutions	Collaborate in national research and adapt/develop, release technologies/information specific to the region, multiply and demonstrate.
4	Government organizations (ATA, EHDA)	Enhance and support capacity in vegetable development program, training, advisory services Facilitate introduction of technologies to enhance production and handling of export commodities at global level
5	Ethiopian Seed Growers and Processors/ Enterprise/ input suppliers/ Private Companies and other NGO's	Strengthening seed system and facilitation of seed law policies/ demand driven input supply/ mechanization of vegetable production (technology introduction, technology transfer, knowledge and skill).
6	Small scale farmer associations, Primary cooperatives and unions	On farm technology evaluation, multiplication, adoption and dissemination, input supply and provide market information and involved in collecting and preparing vegetables for export
7	Ministry of Water Irrigation & Energy	Undertake the management of water resource Involve in the mapping & knowledge-building around water resources Enforce water use policy
8	Ethiopian Standard Agency	Develop & implement national standards to regulate, import materials quality Regulate the quality of fresh vegetable products with Conformity Association Enterprise of Ethiopia
9	Ministry of Trade	Develop and implement policy issues facilitating production and marketing of vegetable crops for domestic and export
10	Ministry of Industry	Facilitate expansion of agro-processing industries and strengthening linkage among different stakeholders (provide information for research for development of technologies for agro processing industries)
11	Ethiopian and Regional Seed Enterprises	Facilitate and multiply adequate quantity of improved seed for improved varieties
12	Agro-Processing Industries	Technology demand, development of value added products and provide technical support
13	National and Regional Soil Testing Laboratories	Provide advisory services and collaborate in soil related research.
14	Ethiopian Food, Beverage and Pharmaceuticals Development Institute	Provide training and advisory services, development and implementation of need based development strategies and policies and provide export market expertise.
15	Oromia Irrigation Development Agency (OIDA)	Cooperate in providing improved irrigation technology at research Centers

16	Ethiopian Biodiversity Institute (EBI)	Germplasm exchange, conservation and maintenance for research, collaborating in research
17	Quality & Standardization Authority	Information exchange
18	Ethiopian Public Health Research Institute	Joint research and information exchange
19	Central Statistic Agency Ethiopia (CSA)	Provides of official statistic information on the production and productivity of vegetable crops in the country
20	International Research Institutes (AVRDC, NRI, IPGRI, KOPIA, ACIAR, ICIPE, ASARECA, etc.)	Involve on collaborative project development and implementation, capacity building, provide germplasm and information in recent scientific advancements.

Benchmarking

As part of the external environmental factors, it is also a cogent exercise to examine the potentials of the crops which can be exploited by drawing lessons from other countries that have advanced levels of research achievements. Accordingly, comparisons, in terms of diversity of crops grown, area coverage, production and productivity were made between the status available in the national research system, countries with the highest records (China and India) and that of the world which, for the purpose of this strategy, are considered as benchmarks (see Table 4). In terms of production, Ethiopia's share of production of for major warm season vegetables such as tomato, onion and pepper is negligible and it is many folds lower than the major producers (Table 5). In terms of crop diversity grown, the major warm season crops grown in Ethiopia are only onion, tomato and pepper whereas the production of other warm season vegetable crops such as pumpkin, squash and guards, cucumber, watermelon, melon, egg plant and okra are almost negligible.

The wide productivity gap between the bench-marked nations and Ethiopia is mainly because of sufficient number of highly trained researchers at each discipline, and higher level of technological advances in facilities, acquisition and maintenance of diverse gene pool, use of biotechnological tools geared toward generation of hybrid varieties, protected horticulture (advanced climate control and fertigation systems). Therefore, step by step building of capacity of researchers and facilities is unequivocal to narrow the productivity gap.

Table 4. Comparison of area, production and productivity of major vegetables of Ethiopia with major producers and the world average

Crop	Country	Area (ha)	Area ratio	Production (ton)	Production ratio	Productivity (t/ha)	Productivity ratio
Onion	Ethiopia	21,865		219189		10.5	
	China	1025000	46.9	2600000	11.9	22.0	2.1
	India	1051527	48.1	16813010	76.7	16.0	1.5
	USA	60000	2.7	3277460	15.0	54.6	5.2
	Kenya	7751	0.4	112243.6	0.5	11.2	1.1
	World	4296495	196.5	83355752	380.3	19.4	1.9
Tomato	Ethiopia	7,237		55514		9.6	
	China	1000000	138.2	50000000	900.7	50.0	5.2
	India	879632	121.5	18226635	328.3	20.7	2.2
	USA	150140	20.7	13206950	237.9	88.0	9.2
	Kenya	24554	3.4	503172	9.1	20.5	2.1
	World	4813312	665.1	162520469	2927.6	33.8	3.5
Pepper (dry)	Ethiopia	136,504		316561		2.3	
	China	44000	0.3	300000	0.9	6.8	2.9
	India	792000	5.8	13760000	43.5	1.7	0.3
	Kenya	2500	0.0	3000	0.0	1.2	0.5
	World	197910	1.4	3458634	10.9	1.8	1.0

(Source: CSA, 2014; FAOSTAT, 2014)

Assessment of Internal Environments

Assessment of strengths and weakness of the program in terms of capacities that exist within the EIAR system such as resources (human, physical and financial resources); technical or technological and organizational capacity, functional integrations within and between disciplines were thoroughly examined. Inter- and intra- disciplinary integrations, complementarities and synergies were also assessed. Furthermore, technologies available for warm season vegetable since the start of research in the country and required with regard to the current and future demand of the farming communities were analyzed (Table6)

Strengths, Weaknesses, Opportunities and Challenges by the Research Themes

Table 5. Internal and external situations analyses on warm season vegetables research

Thematic area	Internal Environment/situation		External Environment/situation	
	Strength	Weakness	Opportunities	Challenges
Breeding and Genetics	• Agro ecologies based research centers; • Established research system (modest research experience and resources); • Availability of varieties of tomato, onion and hot pepper.	• Insufficient and lack of systematic genetic resource collection, introduction and management system; • Limited varieties (ops and hybrids) with high yield and desirable quality; • Lack of varieties for international export market and agro-processing industries; • Limited varieties adapted to different production season, agro-ecologies and production system (protected cultivation, organic production and home garden); • Limited breeding for stress resistance againast major pest and diseases and prevailing enviromental stresses (heat, salinity, drought); • Lack of strategic breeding for development of functional and nutraceutical products; • Inadequate facility and frequent training for researchers and technicians on modern breeding tools • Limited institutional and resource capacity as a result of insufficient national priority given to vegetable research;	• Favorable agro-ecology, potential irrigation water, expansion of micro irrigation schemes, identified growth corridors; • Availability of genetic diversity, though narrow, for some of vegetable crops such as okra pumpkin and chilli; • Presence of policies and regulations on germplasm exchange and introduction and plant quarantine; • Availability of export oriented commercial vegetable farms and collaborating institutions (EHDA, EHPEA, ; • Availability of modern biotechnological tools and facilities elsewhere to adopt, adapt and use; • High demand of varieties especially for export market and agro-processing industries; • Involvement of International and local private companies on introduction, adaptation and	• Limited access to broad germplasm; • Climate change , quarantine pests and diseases and prevailing environmental stresses (heat, salinity, drought); • Lack of seed system and organizations involved in multiplication of adequate and quality seed; • High turnover of skilled research staff and • Poor linkage of the research with other stakeholders along the value chain.

		• Limited capacity of using modern biotechnological tools (MAS and DH techniques);. • Lack of capacity in bioinformatics, genotyping, sequencing and their utilization in molecular breeding and • Shortage of breeder pre-basic seeds in sufficient quantity and quality.	registration of varieties and • Availability of decentralized research on regional, federal and higher learning institutes.	
Crop protection	• Pest management practices are available for several major pests of vegetable crops; • Continuous registration of new agrochemicals; • Acceptable achievements in generating arthropod pest management technologies and information and • strong contribution to national and international scientific communities through publication , documentation and distribution of outcomes of agricultural entomology researches.	• Limited information on biology and ecology of pests; • Insufficient IPM packages and pesticide based pest management; • Limited or absence of basic research on major arthropod pests and • Recommended arthropod pest management methods so far were not IPM oriented.	• Possibility of acquiring IPM options from different research institutes and countries; • Encouraging policy and public and private investment on protection; • High demand for arthropod management technologies by different clients and • availability of web based arthropod pest information.	• IPR issues and absence of policy for the regulation of bio-control options; • Frequent pest outbreaks due to changing environment and tropical nature of the country; • Ineffective quarantine/ regulatory system and surveillance; • Accidental introduction of new invasive arthropod pests to the country and • Absence of entomology extension and advisory system.
Agronomy and Physiology, Nutrient and Irrigation water management	• Availability of blednded fertilizers and construction of fertilizer factories • Increasing focus on warm season vegetables	• Limited and blanket recommendations for different production season, agro-ecologies, production system and crop types • Lack of standardized modern seedling propagation techniques; • Lack efficient water management techniques; • Limited integrated nutrient management	• Availability of precision agriculture technologies (remote sensing) elsewhere to adopt, adapt and use; • Government policy and focus on full package for increased productivity and production to realize food security; • Availability of physiological	• Reliance on chemical fertilizers • Climate change causing recurrent drought and famine limiting farmers capacity to utilize full packages; • Lack of equipments in physiological research and • Less focus on human power development programs in the

		system; • Limited information on vegetable cropping system; • Lack of agronomic recommendations for emerging protected , organic, and home garden vegetable production system; • Limited focus on physiological research; • Limited utilization of crop modeling tools and • Less focus on clustering of environments against disease pressure, high yield and quality.	facilities elsewhere for application to incorporate physiological traits and • Wide availability and applicability of crop modeling tools to predict future crop production senarios.	area of crop physiology.
Quality and Postharvest Management	• Central and satellite labs for quality and nutritional analysis set by EIAR; • Some post-harvest handling (PPH) and semi- processed value added technologies and experiances are available.	• Absence of vegetable based value added food products; • Lack of small scale preservation and processing technologies; • Limited awareness on importance of vegetables in terms of nutrition and consumption; • Lack of strategic research on development of functional and nutraceutical products from vegetable crops and • Absence of effective and simple packaging technologies.	• Favorable policy incentives for agro-processing industries for export market; • Common certification setting(EHPEA); • Increased local demand for processed vegetable products; • Possibility of acquiring technologies related to postharvest management and value addition and	• High investment cost of post-harvest technologies • Absence of local-GAP, strict global food safety standards and costly certification process • Unfavorable legislations on import substitution • Lack of investment in sector-specific infrastructures and logistics
Agricultural Mechanization		• Lack of small-scale farm implements (planters, transplanter, threshers, seed extractor, land leveler, harvester, magnetic sprayer, mechanical weeder); • Inefficient water lifting devices (standardized pumps), transport mechanisms, naturally ventilated short	• Emerging engineering industries to modernize vegetable industry through developing equipment for PPH(post harvest handling) managements, packing and processing.	• Advanced and expensive agricultural equipment in vegetable value chain makes the technologies unaffordable by smallhoder growers

		term storage structures.		
GIS and agro-meteorology	• GIS and agro meteorology research units are established in most research centers	• Lack of GIS based suitability map for major vegetable crop production	• Sophisticated GIS and agro-meteorology Technologies available worldwide	• Big technological and research capacity gap and the technologies are expensive
Technology multiplication		• No involvement in vegetable seed multiplication • Lack of seed multipler within EIAR except the program	• Strong demand from stakeholders for improved seed	• Lack of seed system and absence of responsible vegetable seed multiplying enterprises • Limited facility and expertise in vegetable seed quality research
Agricultural Economics, extension and gender		• Weak delivery of existing technologies to producers; • Poor linkage among stakeholders especially the private sector; • Limited information on vegetable technology adoption and impact; • Limited awareness of vegetable production technologies, consumption post harvest and utilization	• High demand for vegetables products • Existence of vast extension system (GOV & NGOs') and supportive technology promotion policy, marketing systems, etc. to adopt • Expansion and improvement of communication, physical infrastructures	• Weak linkage among extension actors

Capacity Building		• Lack of planned and specialized training (short and long); • Limited research facilities (laboratories and equipments for advanced physiological, molecular pathological data collection and seed test, efficient irrigation system, cold stores, post harvest storage facilities, seed laboratories, green houses, lath houses, offices, machineries, vehicles) ; • Shortage of field and laboratory supplies; • Inadequate budgeting for research operations and capacity building; • Inefficient procurement process and • Limited organizational structure of the program.	• Availability of graduate horticulturist on the market	• Continuous turnover of experienced research staff • Inefficient procurement system for utilizing the available resources • Inadequate budget for procurement of required facilities

Strategic Issues Facing the Warm Season Vegetables Research

The key strategic issues for intervention were categorized in to technological packages, capacity building and organizational structure of warm season vegetable research program.

Technological Packages: Since the start of vegetable research in the country, efforts have been made to improve vegetable production with improved technologies (varieties, crop management practices, pest control recommendations and post harvest technologies). However, there are still gaps, in the major strategic issues identified to be intervened in the following thematic areas: 1) Genetics and breeding; 2) Agronomy, physiology and nutrient management 3).Irrigation water management; 4) Crop protection; 5) Technology multiplication 6) Agricultural mechanization; 7) Food science, postharvest technology and nutrition; 8) GIS and agro-meteorology; and 9) Agricultural economics, extension and gender. The strategic issues are presented under each thematic area.

Research Capacity: Almost all research centers including the co-coordinating center Melkassa Agricultural Research Center (MARC) have limited research facilities, infrastructure and qualified and senior research staff.

Organizational Structure: Vegetable crops research is recently reorganized from a single commodity into two separate programs; and yet several vegetable crops are considered in a research program. Warm season vegetable research program, for instance, addresses capsicum *spp*, tomato, onion, snap bean, okra, egg plant, amaranths, cucurbits etc. Further restructuring the research programs into groups of specific crops will help to focus on delivering appropriate technologies.

Table 6.List of thematic areas and strategic issues

Thematic areas	Strategic issues
Genetics and breeding	• Limited and lack of access to broad genetic resources
	• Improved varieties (OP and hybrid) with high quality, yield and resistant to biotic and abiotic stresses for diverse agro-ecologies and uses (nutrition, processing, export market, protected cultivation and organic culture)
	• Basic research knowledge and skill
	• Application of biotechnology
	• Maintenance breeding and breeder seed
Agronomy , Physiology and nutrient management	• Seedling propagation techniques and nursery management
	• Agronomic practices, integrated nutrient management and cropping system
	• Production systems (organic, protected and home garden production)
	• Physiology
Irrigation water	• Irrigation agronomy (efficient water management)
Crop protection	• Basic information on major vegetable pests
	• IPM packages
	• Pesticide residues
	• Pesticide resistance
Technology multiplication	• Adequate and quality seed production
	• Seed system
Agricultural Mechanization	• Small-scale farm implements
	• Pump, transportation mechanisms, storage structures
Food science, postharvest technology and nutrition	• Value added food products
	• Nutritional characteristics and quality related traits
	• Postharvest management
	• Packaging technologies
climate smart agriculture (CSA)	• GIS for operation of farm practices
	• Vegetable production suitability map
Agricultural economics, extension and gender	• Technology promotion
	• Linkage among stakeholders especially the private sector
	• Inclusiveness (gender, youth & disabled)
	• Farming systems
	• Adoption and Impact
	• Marketing and Policy
Capacity Building	• Physical
	• Human
	• Finance

Research Themes and Strategic Interventions

The research strategic interventions are outlined below in short (2016-2020), medium (2021-2025) and long-term (2026-2030) interventions, and under each of these by the identified thematic areas of intervention.

Table 7. Strategic interventions planned to address critical issues facing the warm season vegetables research commodities in the short-, medium- and long- terms

Strategic issues	Strategic Intervention		
	Short-term (2016-2020)	Medium-term (2021-2025)	Long-term (2026-2030)
1. Genetics and Breeding			
Capsicum wilt	• Introduction of wilt resistant lines • Collection and characterization • Parental selection and evaluation	• Understand the inheritance mechanism • Crossing block establishment • Grafting between selected lines	• Hybrid development
Access to broad genetic resources	• Strengthen collaboration with international institution (AVRDC, IPGRI) for germplasm source; • Systematic genetic resource collection, introduction and management of desirable traits (stress tolerant, yield and quality); • Initiate crossing and generate genotypes from segregating population.	• Continue enriching germplasm base through collection and introduction with desirable traits • Strengthening crossing and generate genotypes from segregating population	• Continue introduction, collection and collaboration with international institutions for sources of germplasms; • Strength crossing block and generate genotypes from segregating population;
Improved varieties (OP and hybrid) with high quality, yield and resistant to biotic and abiotic stresses for diverse agro-ecologies and uses	• Introduction, adaptation and registration of commercial varieties with high yield and desirable quality and uses (processing, export market); • Development of varieties for high yield and quality and • Development of varieties for export market and processing industries.	• Introduction, adaptation and registration of commercial varieties with high yield and desirable quality and uses (processing, export market); • Development of improved varieties with high production potential, biotic and a biotic stress tolerance; • Development of varieties for various uses (export market, processing, protected and organic culture) and • Development of parental lines for hybrid development for tomato and capsicum.	• Introduction, adaptation and registration of commercial varieties with high yield and desirable quality and uses (processing, export market); • Develop varieties for different production system (protected, organic, rain fed and irrigation); • Development of hybrid tomato and capsicum varieties for yield and quality and • Development of improved varieties with high production potential and resistance to major disease and other stresses (salinity and heat).

Basic research knowledge and skill	• Generate basic scientific information regarding stress resistant, inheritance and gene action • Generate information on nutritional quality of warm season vegetable varieties and selected germplasms	• Generate basic scientific information regarding stress resistant, inheritance and gene action	• Generate basic scientific information regarding stress resistant, inheritance and gene action
Application of Biotechnology	• Molecular characterization of varieties and /or germplasm of tomato, capsicums, okra	• Continue to characterize available germplasms of tomato, capsicums, okra using molecular tools with desirable traits such as disease , heat, drought resistance; • Initiate and employ MAS in capsicum and tomato breeding and • Initiate and employ of DH line development and evaluation for desirable traits for capsicum.	• Continue to characterize available germplasms of tomato, capsicums, okra using molecular tools; • Strengthening of MAS in capsicum and tomato breeding and • Strengthening of DH development and evaluation for desirable traits in capsicum.
Maintenance breeding and breeder seed	• Maintain and produce breeder seed of released warm season vegetable varieties with sufficient quantity and quality	• Continue to maintain and produce breeder seed of released warm season vegetable varieties with sufficient quantity and quality	• Continue to maintain and produce breeder seed of released warm season vegetable varieties with sufficient quantity and quality
2. Agronomy, Physiology and Nutrient Management			
Seedling propagation techniques and nursery management	• Develop nursery management technologies • Plant protection in vegetable nursery	• Adoption of nursery media technologies • Development of nursery media from local materials	• Water management and hardening of seedlings at nursery • Plant nutrition and its management in vegetable nursery
Physiology	• Determine seed germination rate, dormancy period and priming techniques and development); • Determine response of different vegetable crop varieties under greenhouse.	• Conduct crop physiological studies (water use efficiency, photosynthetic efficeincy, nutrient use efficiency,crop growth and development)	• Continue crop physiological studies (water use efficiency, photosynthetic efficeincy, nutrient use efficiency,crop growth and development)

Agronomic practices, integrated nutrient management and cropping system	• Refine and update production technologies (fertilizer rate, spacing) for tomato, capsicum and onion; • Generation of cropping systems for different climatic conditions (crop rotation, intercropping); • Optimize organic and inorganic fertilizer combination ratio for major vegetable crops and • Determination of optimum nutrient application for different vegetable and agro-ecologies.	• Develop vegetable based cropping system (crop rotation, intercropping pattern); • Continue determination of optimum nutrient application for different vegetable and agro-ecologies and • Determine soil test-based crop response information.	• Determine optimum micro nutrient rate and frequency of application in tomato, onion and capsicum • Continue generation of cropping systems for different agro- climatic conditions (crop rotation, intercropping)
Production systems (organic, protected and home garden production)	• Identification and adoption of home garden culture for urban and pre urban agriculture.	• Development of crop management practices for organic production (biofertilizer, biopesticide, plant density, mulch); • Development of crop management practices for protected culture and • Development of crop management practices for home garden production (media, density).	• Development of vegetable home garden production model for urban and pre-urban corridors • Development of technologies for protected cultivation (tomato, cucumber, capsicum (spacing, fertigation and irrigation)
3. Irrigation water management			
Irrigation agronomy (efficient water management)	• Determine crop water requirement coefficent and irrigation amount and frequency	• Development of efficient water management (micro-irrigation and fertigation and irrigation scheduling) available for major vegetables	• Continue development of efficient water management (micro-irrigation and fertigation and irrigation scheduling) available for major vegetables
4. Crop protection			

Basic information on major vegetable pests	• Exploratory insect, disease and weed pests surveys • Determine seasonal abundance of major pests and associated regulatory factors	• Assess crop losses due to major pests; • Studies on mechanism and breeding for resistance and • Develop pest forecasting system.	• Generate information on outbreak, biology and ecology of pests of vegetable crops; • Study of biology of major pests under laboratory condition; • Epidemiology and population dynamics studies of major pests
IPM packages	• Integration of identified cultural control methods with other tactics • Trap networking for major disease and insect pests	• Assess the efficacy of cultural, mechanical and physical control methods on controlling major pests; • Introduce and evaluate exotic natural enemies against major pest problems and • Determine indigenous natural enemy complex associated with major pests.	• Assess the efficacy of microbial products for the control of major pests; • Studying genetics of resistance and incorporating host plant resistance to IPM; • Identification of source of resistance against major pests; • Release and assess the establishment and effectiveness of natural enemies in bio-control method.
Pesticide residues	• Awareness creating through training	• Continue awareness creating through training	• Continue awareness creating through training
Pesticide resistance	• Determine occurrence of pesticide resistant biotypes of major pests; • Conduct studies on reduced rate and critical time of application; • Resistance management studies and • Training on and demonstration of rational use of pesticides	• Continue determining occurrence of pesticide resistant biotypes of major pests; • Evaluation of new and IPM compatible pesticides; • Strengthen Resistance management studies and • Continue training on and demonstration of rational use of pesticides.	• Continue determining occurrence of pesticide resistant biotypes of major pests; • Evaluation of new and IPM compatible pesticides; • Strengthen Resistance management studies and • Continue training on and demonstration of rational use of pesticides.
5. Technology multiplication			

Adequate and quality seed production	• Basic and pre-basic seed production of improved varieties of vegetables and • Development of harvest and post-harvest seed management techniques.	• Continue basic and pre-basic seed production of improved varieties of vegetables • Continue development of harvest and post harvest seed management techniques	• Continue development of harvest and post-harvest seed management techniques; • Production and supply of early generation continue;
Seed system	• Establishment of innovative platform for production and marketing vegetable seed production • Providing technical support for community based seed producers for quality and sustainable seed production	• Continue establishment of innovative platform for production and marketing vegetable seed production • Continue providing technical support for community based seed producers for quality and sustainable seed production	• Continue establishment of innovative platform for production and marketing vegetable seed production and • Continue providing technical support for community based seed producers for quality and sustainable seed production
6. Agricultural Mechanization			
Small-scale farm implements	• Development of manual and engine operated tomato seed extractor • Undertake inventory of locally existing technologies	• Conduct evaluation, verification of local existing technologies and demonstration • Development of vegetable seed planters, seed threshers	• Development of magnetic pesticide sprayers.
Pump, transportation mechanisms, storage structures		• Develop appropriate improved storage facilities through adoption, introduction and reverse engineering and copying from public domain	• Continue to develop appropriate improved storage facilities through adoption, introduction and reverse engineering and copying from public domain
7. Quality and Postharvest Management			
Quality and Postharvest management	• Study nutritional characteristics and quality related traits of vegetables; • Determine post-harvest losses of major vegetables; • Introduce post-harvest management technologies of vegetables for fresh market and processing; • Development of packaging technologies for different vegetables and	• Study nutritional characteristics and quality related traits of vegetables; • Determination of quality standards for industrial and export market; • Development of processing and preservation techniques; • Develop post-harvest management technologies of vegetables for fresh market and processing;	• Development of functional and nutraceutical vegetable based food products; • Nutritional characteristics and quality of related traits vegetables; • Promote post-harvest management technologies of vegetables for fresh market and processing; • Development of packaging

	• Develop value added products.	• Development of packaging technologies for different vegetables and • Continue develop value added products.	technologies for different vegetables and • Continue develop value added products.
8. GIS and agro-meteorology			
Vegetable production suitability map	• Expanding vegetable crops -climate suitability/stress mapping for the representativeness of the existing testing sites and annex new/potential sentinel sites for vegetable crops research program		• Strengthen integrated soil—vegetable crops--climate continuum (SPAC) modeling for rain-fed and irrigated system to optimize the balance between the multi-location experimentation and the computer based modeling research
GIS for operation of farm practices	• Understanding local climate and farming system dimensions (physical climate, social, economic. farming system etc) for targeting the right vegetable crops technology to the right environment	• Evaluation of the potential impacts of vegetable G*E*M combination under various vegetable growing belts towards reducing the wider yield gaps (farmers/actual yield, experimental or attainable yield and the potential yield/biological maximum); • Optimizing response to the prevailing and the resurgence of diseases and insect pests in vegetable production under the climate changed future Ethiopia.	• Optimize vegetable breeding for the shift/change in temperature (beyond the maxima) and decline in water demand under the highly likely climate changed future dates in Ethiopia
9. Agricultural economics, extension and gender			

Technology promotion	• Demonstration and popularization of major vegetable technologies; • Develop and distribute various communication material and • Organize trainings, field days and travelling workshops involving stakeholders.	• Continue demonstration and popularization of major vegetable technologies to new areas; • Coninue develop and distribute various communication material and • Continue organize trainings, field days and travelling workshops involving stakeholders	• Continue demonstration and popularization of major vegetable technologies; • Coninue develop and distribute various communication material Continue organize trainings, field days and travelling. workshops involving stakeholders
Linkage among stakeholders especially the private sector	• Establish and effectively use innovation platforms for development and dissemination of vegetables technologies	• Strengthen and promote innovation platforms for development and dissemination of vegetables technologies	• Strengthen and promote innovation platforms for development and dissemination of vegetables technologies
Inclusiveness (gender, youth & disabled)	• Develop working modality to strengthen the participation of women and youth in vegetable research and promotion • Promote gender main streaming in vegetable research	• Continue strengthening participation of women and youth in vegetable research and promotion • Continue promotion of gender main streaming in vegetable research	• Continue strengthening participation of women and youth in vegetable research and promotion • Continue promotion of gender main streaming in vegetable research
Farming systems	• Survey, diagnose and document the social, economic and cultural values of vegetable production and its constraints	• Survey, diagnose and document the social, economic and cultural values of vegetable production and its constraints	• Survey, diagnose and document the social, economic and cultural values of vegetable production and its constraints
Adoption and Impact	• Determine the extent of adoption of vegetable technologies and their impact	• Determine the extent of adoption of vegetable technologies and their impact	• Determine the extent of adoption of vegetable technologies and their impact
Marketing and Policy	• Conduct value chain study and identify constraints at different stages of the value chain • Generate cost of production for major vegetable crops	• Conduct value chain study and identify constraints at different stages of the value chain	• Conduct value chain study and identify constraints at different stages of the value chain • Cost of production for major vegetable crops estimation
10. Capacity Building			

Physical	• Establishment of facilities and infrastructures ((laboratories, office, greenhouse, lath house, drip irrigation, vehicles, cold stores, storage facilities, office and laboratory equipments)	• Establishment of standard greenhouse and screen houses • Construct office and laboratory building and acquire the necessary facilities	• Upgrade lab and office facilities
Human Resource	• Recruit qualified researchers for all disciplines; • Strengthen capacity and familiarize researchers with modern scientific tools through long and short term trainings and periodical mentorship; • Organize short term and on-job trainings for support staff and • Organize experience sharing and exchange visits.	• Maintain adequate level of qualified research staff ; • Strengthen capacity and familiarize researchers with modern scientific tools through long and short term trainings and periodical mentorship; • Organize short term and on-job trainings for support staff and • Organize experience sharing and exchange visits.	• Maintain adequate level of qualified research staff; • Strengthen capacity and familiarize researchers with modern scientific tools through long and short term trainings and periodical mentorship; • Organize short term and on-job trainings for support staff and • Organize experience sharing and exchange visits.
Finance	• Allocate adequate budget, • improve the procurement process and release budget timely	• Allocate adequate budget • improve the procurement process and release budget timely	• Allocate adequate budget, improve the procurement process and release budget timely

The Next Steps

Following the approval of the strategy document by the top management of EIAR, it is essential to prepare the implementation plan, without which this strategy is not going to reach fruition. The implementation plan document will come out as Volume II of the research strategy, which will serve as the blueprint to guide the National Warm Season Vegetable Research Commodity for the next fifteen years (2016-2030). The major contents of the implementation plan will revolve, among others, around the following topics:

- Develop implementation plan;
- Develop monitoring and evaluation plan;
- Develop impact assessment plan and
- Develop reassessment plan for the strategy.

In order to expedite the development of the implementation plan, it will be important to develop a common guideline that will serve the EIAR Planning, Monitoring and Evaluation Directorate to provide guidance to the research teams develop implementation plans. This guideline is useful to communicate the goals of the strategic plans and establish uniform approaches. The guideline will contain important considerations in planning a project(s) from the developed strategic plan, including building research teams of various roles and levels. It will generally be of importance that researchers, planners and evaluators will need to become familiar with the guideline to prepare successful projects from the strategic plans as well as provide realistic estimates of resource requirements for implementing the strategic interventions projected for the short-, medium- and long-term timeframes. The guideline will, therefore, be prepared with the intention of providing a common structural and conceptual framework that can be followed by the respective teams of research commodities for preparing the implementation plans of their respective strategies.