



MINISTRY OF AGRICULTURE
SULTANATE OF OMAN



**AGRICULTURE AND LIVESTOCK
FIVE-YEAR RESEARCH STRATEGY**

2011-2015

Directorate General of Agriculture & Livestock Research

January 2011



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His Majesty Sultan Qaboos Bin Said

Ministry of Agriculture (MoA), Sultanate of Oman
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FOREWORD

The Seventh Five Year Plan (2006-2010) indeed witnessed a quantum leap in agricultural research in terms of quality and magnitude in the Sultanate. The allocation of about 12 million Omani Rials for research programs contributed enormously in the improvement of infrastructure and applied research with the achievement of positive results in respect of : production per unit area, water use efficiency and utilization of non conventional water resources (saline water and treated waste water) for agricultural production, application of eco-friendly pesticides and biological control of pests and diseases, and production of improved fruit tree seedlings, besides raising the productivity of Jimah Tissue Culture Laboratory to approximately 50 thousand date palm seedlings per year. Moreover, productive fruit tree seedlings were provided to the farmers and more healthier and productive livestock animals were provided to farmers and herders annually as a result of improvement in the research, surveillance, monitoring and diagnosis of animal diseases.

Agriculture and livestock research strategy (2011-2015) is a key document of the Directorate General of Agricultural and Livestock Research, which shows our vision, mission and goals to improve the quality of research in the relevant priority areas in consonance with country's vision 2020. This strategy has been an outcome of several meetings and brainstorming among the researchers, extensionists, farmers and policy makers of different national stakeholders. The strategy consists of 10 mega-programs including 31 research projects and 5 supportive services projects. These mega-programs and projects have been designed to be in line with governmental policies for agricultural research in the Eighth Five Year Plan (2011-2015). The research activities within the umbrella of the strategy will be reviewed and evaluated annually to ensure quality of the research in achieving their objectives to focus on the technology transfer of outcomes to the end users.

So far, about 12 million Omani Rials are available for agricultural and livestock research from the Ministry of National Economy for the next five years, in addition to about 3 million Omani Rials from Agricultural and Fisheries Development Fund for the current approved research projects. It is worth mentioning here that the total number of Omani researchers at the beginning of 2011 is 129 of which 12 are with PhD and 17 would accomplish their PhD within the Eighth Five Year Plan.

In conclusion, I do sincerely hope that we continue developing human capacity and infrastructure in the coming five years, and look forward to witnessing tangible outcomes of agricultural and livestock research that assist in improving the income of our farming community and contributing to the national GDP.

Dr. AHMED AL-BAKRI
Director General of Agricultural & Livestock Research

1. SULTANATE OF OMAN

The Sultanate of Oman occupies the eastern corner of the Arabian Peninsula, stretching more than 1700 km from the Strait of Hormuz in the north to the frontiers of Yemen in the south. The Musandam peninsula, the most northern point of Oman is separated from the rest of the country by Fujaira, which is one of the United Arab Emirates (Fig. 1). The country is located between latitudes 16° 40'N and 26° 20'N and longitude 51°E and 59° 40'E. It occupies total area of about 309,500 sq. km, of which mountains, deserts and coastal plains represent 16%, 81% and 3%, respectively. It can be divided into the following physiographic regions, (i). the whole coastal plain- the most important parts are the Batinah Plain in the north, which is the principal agricultural area, and the Salalah Plain in the south; (ii). the mountain ranges- that run in the north close to the Batinah Plain is the Al-Jabal Al-Akhdar with a peak at 3,000 meters and in the extreme southern part of the country, with peaks from 1,000 to 2,000 meters and (iii). the interior regions- which lay between the coastal plain and the mountains in the north and south consist of several plains with elevations not exceeding 500 meters.



Fig. 1. Geographical Regions of Oman

The climate varies from arid in the interior regions, to humid in coastal areas to tropical in the southern parts of the country with a temperature range from below zero (in Al-Jabal Al-Akhdar and Al-Jabal Shams) to 50°C in summer in the desert. The average annual rainfall is about 100 mm, mostly distributed between November and February, except in the Dhofar region where there is monsoon rainfall (200-250 mm) during *kharif* (July-September) period.

2. AGRO-ECOLOGICAL REGIONS OF OMAN

Two main agro-climatic zones are recognized in Oman based on parameters which influence potential of land, water resources and cropping patterns: Northern Oman including Batinah Coastal plain, Interior Oman and Dhahira plains, Al-Jabal Al-Akhdar and Sharqiya plains and Southern Oman, Dhofar including Salalah plain, Dhofar Jabal and Najd.

Northern Oman

Batinah Coastal plain

By far the most important agricultural area in Oman is the Batinah region. It is a low-lying alluvial plain extending for about 240 km from Muscat to the borders with U.A.E., and extending about 30 km inland from the coast. It is located between the Hajar mountain ranges and the Gulf of Oman. The Batinah region occupies almost 60% of the agricultural production and has witnessed dynamic agricultural development in recent years. Crop production depends entirely on irrigation, the main crops being dates, fruit crops, alfalfa, vegetables, and other forage crops.

The climate of the Batinah region is characterized generally by high temperatures reaching 48°C in the summer and mild temperatures ranging from 15°C to 24°C in the winter. Relative humidity may reach over 90%. Daily wind runs are comparatively short and mean annual rainfall ranges from 76 to 100 mm. Over pumping of water in the last couple of decades, has led to gradual seawater intrusion causing irrigation water more saline. As a result, several agricultural lands of the coastal areas have become unsuitable for cultivation.

The Batinah region can be visualized as divided by the main highway to U.A.E. into two sub-zones, namely one extending from the main highway to the coast (the coastal sub-zone) and the other extending to the west (the inland sub-zone). Although climate-wise these two sub-zones are indistinguishable, differences exist in microclimate, quality of irrigation water, cropping pattern and the age of plantations. The inland sub-zone has developed more recently and modern systems of irrigation are in use. The coastal sub-zone includes old date plantations of low productivity because of salinity. They are usually intercropped with other tree and forage crops. The plant genetic resources for food and agriculture (PGRFA) diversity within these two sub-zones may have been affected due to changes in the quality of irrigation water.

Interior Oman and Dhahira plains

The interior plains lie within the inner foothills of the Hajar mountain ranges and constitute a transitional range classified either as the mountain region or the interior lowlands. They include Buraimi plain, Ibri, Wadi Quriyat, Bahla and Nizwa. The main crop in this zone is dates occupying 9463.2 ha (MoA, 2005*). Intercropping with fruit trees is practiced but not to the extent of that in the Batinah. In order of importance, alfalfa follows date cultivations with 5.6% of the cultivated land, (38368.1 ha) (MoA, 2005*). The climate of this zone is characterized by high temperatures during summer. Somewhat lower humidity prevails as compared to that in the Batinah coastal plain. The development of the ground water resources of the interior plains and the wadi region has been achieved either through the traditional falaj system or through wells. Nearly 20% of the total area under irrigation is served by the falaj system and 74% by wells (Agriculture Census, 2005). The range of farm size irrigated from wells is 0.5 to 3.0 ha. Water is pumped in a small distribution reservoir from where it is channeled to the fields through cement canals. Farmers in the interior plain practice basin or border irrigation. The quality of water of the interior plains varies extensively. Most falaj water is generally of good quality.

Al-Jabal Al-Akhdar or Saiq Plateau

Al-Jabal Al-Akhdar reaches an altitude of 3000 m. It constitutes a unique climatic zone as compared to any other region of the Sultanate. It is characterized by lower winter temperatures, which satisfy the chilling requirements of number of temperate deciduous fruit and nut trees such as pomegranates, peaches, apricots, apples, pears, walnuts and almonds. The summer temperatures average 30°C. Annual rainfall (300 mm) is significantly higher than elsewhere in Oman, with the exception of Dhofar Jabal, and it is distributed throughout the year.

Sharqiya Plains

In wadi Al Batha, agriculture is concentrated around Ibra, Ad-Dariz, Al-Ghabbi and Al- Wafi. The area under crops is about 1500 ha in 26 oases irrigated mainly by falaj system. The Sur plains seem to have a very limited potential for development due to sea water intrusion. In contrast, the Wadi Batha plain seems to offer best potential for agriculture because of the existence of highly suitable soils associated with good quality groundwater in the Jalaan district around Al-Kamil and Al-Wafi. Irrigation in this region is achieved by falaj systems. Private farms employ flood or furrow irrigation methods.

Southern Oman

The southern region occupies approximately one third of the area of the Sultanate. Apart from the coastal plain extending from Raysut in the west past Salalah, the woody hills reach up to

*MoA. 2005. Agriculture Census - 2005. Directorate General of Planning and Investment Promotions. Department of Statistics and Information. Ministry of Agriculture, Oman.

1500 m elevation behind the plain constitute a separate climatic zone. The southern slopes of the hills known as the 'Jabal' are rather steep, deeply incised narrow wadis, and receive southern monsoon rains. The northern slopes called 'Najd' are much gentler and the wadis dissecting them are wider and less deeply incised.

Salalah Plain

Salalah plain is located in the coastal area of the southern province of Dhofar. Dhofar is the only region in Oman to benefit from a substantial amount of rainfall from the southern monsoon Kharif. The average annual rainfall is about 110 mm but can range from about 70 to 360 mm. July-August is normally the 'Wet' period. Ground water derived from aquifers in the central part of plain is of good quality. Some of the spring water is utilized by falaj to provide irrigation water for parts of the plain. Recharge is by underflow from the mountains and from the springs. Irrigation practices and methods are similar to those employed in the Batinah. Modern irrigation techniques are in operation in large commercial farms mainly for the production of forage crops such as Rhodes grass.

Dhofar Jabal

The Jabal mountain ranges compose a separate agro-climatic zone of their own. Rainfall is particularly high, ranging from 600 mm to 700 mm, the highest as compared to any other area in the country, supporting a permanent vegetation cover. The rainfed pasture land is concentrated on some half a million hectares on the Jabals- Qara and Qamar. The Dhofar Jabal maintains two-thirds of the total cattle and one third of the total goat populations in the Sultanate.

Najd

In contrast to the Jabal and the coastal plain, in Najd, there is a quick decrease in precipitation and moisture marked by a rapid transition from the grasslands and savannah-type vegetation found on the Jabal. Temperature is higher in Najd as compared to the plain and the southern slopes. Rainfall in Najd is only in traces. The region is characterized by an extensive carbonate aquifer. Water quality is generally poor and soils are structure less, of poor fertility and highly permeable. Although the agricultural potential of these areas is limited, investigations have identified suitable areas of Najd with potential for agricultural development.

3. AGRICULTURE LAND AND WATER RESOURCES

The results of detailed soil surveys carried out by the Ministry of Agriculture indicated the presence of more than 2.3 million hectares of arable land in the Sultanate. However, the size of the cultivated area is in fact 73,670 hectares (MoA, 2009*). Over half the agricultural area is located in

*MoA. 2009. Annual Agriculture Statistics. Directorate General of Planning and Investment Promotions. Department of Statistics and Information. Ministry of Agriculture, Oman. 74 p.

the Batinah Plain in the north, which represents about 3 % of the area of the country. Seasonal fruit crops occupy the first rank of the total cultivated area in Oman with 37,082 hectares of which 31365 hectares are with date palm. The other cropped area under intercropping includes 28,017 hectares of which 10,735 hectares are with field crops under crop rotation and sequence, which would raise cropping intensity to the extent of 120% (Table 1).

It is apparent that there is an increase in agricultural production in 2009 as compared to previous years and the date palm occupies first in both area (31,365 ha) and production (255,871 tons). Date palm represents 85% of the total area planted with fruits followed by banana, mango, Omani lime, Omani coconuts. Al-Batinah region leads first in the cultivation of vegetables that cover highest of 79% of the area as compared to other regions. Besides, there are also other plant genetic resources such as indigenous grasses, medicinal plants, pastures, trees and shrubs, and forest resources.

Farming systems include production of crops viz. dates and fruits, vegetables, fodder and field crops, as well as livestock such as cattle, sheep, goats, and poultry. Farm holdings vary from less than 0.4 ha to more than 84 ha. Those less than 1.26 ha are about 11% of total farm holdings; those range between 1.26 to 2.60 ha are 65%, while those greater than 12.6 ha are about 23.8%.

Water plays a significant role in the development of Agriculture in Oman, which is largely dependent on groundwater. There are numbers of *afalaj* (falaj-singular), springs (oasis) and wells that provide the source of water for agriculture since ancient times. Of late, desalinated and treated waste-water also form non-conventional sources of water.

Sultanate of Oman is known for its distinctive irrigation systems of springs known as *aflaj* (falaj-singular), which are one of the most important and oldest irrigation techniques established by the ancient Omanis thousands of years ago which is a vital part of the heritage of Oman. There are so far 3,017 live *aflaj* out of total 4,112 which contribute 404 million cubic meters of water to agriculture. Most of the oases are used for irrigation through *aflaj*. The *aflaj* located near or adjacent to the stream *wadis* are often affected by water erosion.

Wells and springs play an important role in the life of the Omani society and are used to provide water to the population and farms for agriculture. There are 127,000 wells providing 720 million cubic meters of water needs of agriculture in the Sultanate. The government has established mega-projects for the maintenance and renovation and repair of wells and springs to reduce loss of water and increase the efficiency of irrigation for agricultural purposes. There are laws and regulations by the government to prevent indiscriminate drilling of water wells.

Table 1. Area (ha) and Production (t) of food crops in Oman from 2005 to 2009

Year / Crops	2005		2006		2007		2008		2009	
	Area	Production	Area	Production	Area	Production	Area	Production	Area	Production
Vegetables	5154.20	119138.00	4704.62	108055.00	5549.16	130360.00	5950.42	141073.00	6185.71	192133.00
Field crops	7643.70	26561.00	7643.70	25206.00	7122.69	25182.00	6842.02	24572.00	14171.85	48448.00
Forage crops	13907.98	539839.00	14376.05	564310.00	15342.44	608743.00	16897.90	662503.00	16230.67	630483.00
Fruit crops	36926.05	307398.00	36926.05	313065.00	37081.93	311769.00	37081.93	319714.00	37082.77	318880.00
Total	63631.93	992936.00	63650.42	1010636.00	65096.22	1076054.00	66772.27	1147862.00	73671.00	1189944.00

Source: MoA, 2009. Annual Agriculture Statistics. Directorate General of Planning and Investment Promotions. Department of Statistics and Information. Ministry of Agriculture, Oman, 74 p.

Sultanate of Oman suffers from water scarcity with annual water deficit of as much as 387 million cubic meters. Recently, the Government of Oman is making efforts towards rationalization of water consumption, exploration of new water resources and recharging of barriers and dams and desalination of seawater and utilization of tertiary treated wastewater mostly in agriculture.

Dams form another important source of water in the Sultanate. There are as many as 31 groundwater recharge dams which capture estimated 997 million cubic meters of water which is equivalent to 78% of the total annual amount of recharge groundwater in the Sultanate (1,295 million cubic meters), since their inception. In addition, there are surface storage dams, which are important sources of stored water at the time of floods flowing through *wadis* from the mountains. The Government of Oman has so far established 61 surface storage dams in its various regions with a total storage capacity of about 13,709 million cubic meters. In addition, the government has constructed 14 more dams- 11 in Muscat and 3 in Musandam, to protect especially against the risk of flooding.

In the Sultanate of Oman, the Government is doing efforts to provide water to its citizens by desalination of seawater as an additional source of water for drinking and household uses. The government has so far established many desalination plants since first desalination plant that began operating in 1976 with the estimated capacity of about one million cubic meters per year. The total production of all available desalination stations is about 418,000 cubic meters per day, equivalent to 152 million cubic meters per year.

The treated wastewater (TWW) has an importance in Oman for use to irrigate plants of garden and road side landscapes as an alternative source of water as well as to recharge the aquifers. There are 51 sewage plants established by the Ministry of Regional Municipalities and Water Resources in different regions. It is expected that the total quantity of treated wastewater would reach up to 270,000 cubic meters per day, which is equivalent to 100 million cubic meters per year, by 2012. At present, the production of treated water is nearly 60,000 gallons per day for use to irrigate parks and green landscapes, which is expected to increase sharply in 2010 after the completion of a sanitation project for the city of Muscat.

4. ANIMAL RESOURCES

The diversified livestock in Oman that include cows, sheep, goats and camels, is on the rise annually with goats representing the highest (1557148 to 1685420), followed by sheep and cows while camels were least (301558 to 326240) (Table 2).

Table 2. Number of different livestock (in thousands) in the Sultanate

Livestock	2004/2005	2007	2008	2009
Cows	302.558	313.580	319.850	326.240
Camels	117.299	122.070	124.520	127.010
Goats	1557.148	1619.990	1652.380	1685.420
Sheep	351.066	366.190	373.520	380.990
Total	2327.071	2421.830	2470.270	2519.660

Source: MoA. 2009. Annual Agriculture Statistics. Directorate General of Planning and Investment Promotions. Department of Statistics and Information. Ministry of Agriculture, Oman. 74 p.

According to Agriculture Census-2004/2005 of the Ministry of Agriculture, there were 24,730,000 poultry birds which included commercial layers and broilers and domestic birds, spread over different regions of the country. In respect of local production of poultry meat, table eggs and fresh milk, it is evident that fresh milk production has rising trend from 2007(47.63 thousand tons) to 2009 (49.57 thousand tons) whereas poultry meat production had decreasing trend (26.5 thousand tons to 21.0 thousand tons), which could be at the expense of table eggs, whose production was found increased (179 million to 187 million) (Table 3).

Table 3. Local production of fresh milk (1000 tons), poultry meat (1000 tons) and table eggs (million) in the Sultanate

Products	2007	2008	2009
Fresh milk	47.63	48.60	49.57
Poultry meat	26.50	20.90	21.00
Table eggs	179	185	187

Source: MoA. 2009. Annual Agriculture Statistics. Directorate General of Planning and Investment Promotions. Department of Statistics and Information. Ministry of Agriculture, Oman. 74 p.

5. DEVELOPMENT OF AGRICULTURE IN THE SULTANATE

Omani agriculture is known since ancient times successfully following primeval means of agricultural production under the harsh working conditions of hunting animals and fishing in the sea. Previously, agriculture in Oman had primitive methods/ materials of production (irrigation, fertilization, varieties and good resistance to pests, harvesting, etc.) with low outputs in terms of quantity and quality of agriculture products. There was absence of diversification, machinery, equipment and modern technology for agricultural development in addition to the lack of infrastructure such as dams and the use of modern irrigation methods. Animal husbandry practices and veterinary services were indigenous and old in nature. Since the *Dawn of the Blessed Renaissance*, the government began adopting a well-planned strategy to finance the

development of balanced multi-sector economy, that included agricultural and livestock sectors. These agriculture and livestock sectors started making the plans and strategies in line with the vision of His Majesty Sultan Qaboos bin Said expressed on 22nd National Day in 1992 through his guidance in these phrases *"We stress the continual importance of agriculture, fisheries and animal husbandry. Our efforts to secure our food requirements cannot succeed if they are dependent on the outside world. The development of productive projects in these vital areas and the encouragement of our people to utilize agricultural land effectively without exhausting our water resources is the only answer. Carefully studied and organized agriculture work can increase this sector of our economy and thus contribute to the provision of food we need"*. Thus, in the context of development adopted by the government, the Ministry of Agriculture developed plans and different strategies through the legislation of many of the agricultural policies and regulations. As a result of concerted efforts in the activities, there is significant increase in the value of agricultural and livestock production from 173.5 million Omani Rials in 2002 to 199.2 million Omani Rials in 2007 at an annual growth rate of 2.9%. This is attributed to the stability of resources of arable land available and the targeted efforts made in the development and modernization of the agricultural sector for more economic efficiency.

Agriculture and livestock research has a pivotal role in supporting agricultural development, which reflected positively on increasing the national production of crops and livestock and improving the livelihood of farming community to contribute to economic and social development of the country. During 1990s, the objectives of the agriculture and livestock research were set based on the priorities within the framework of the agricultural sector strategy of the Ministry of Agriculture & Fisheries, drafted by the Japanese Agency for International Cooperation (JICA). The agriculture strategy was meant to study the agricultural sector situation at that time and to identify the determinants of growth and constraints and develop methodologies and short, medium and long term work plans and programs. There were programs to establish agriculture development centers, research centers and stations with basic infrastructure and farms, agricultural and veterinary clinics. The Ministry has implemented several short and medium term programs and projects to increase the agricultural productivity per unit area and improve the quality of produce and carry out activities on the collection and conservation of indigenous agriculture and livestock resources. During this period, capacity building was the main focus in appointing the new Omani graduates of the Sultan Qaboos University to posts of researchers not only in agriculture and livestock research but also as extension officers in Agriculture Development Centers. This had undoubtedly contributed to capacity development in agriculture research, extension and development in the following areas:

1. Increasing productivity per unit area using the modern scientific methods and research on agricultural production inputs such as water, fertilizers, and pesticides, seeds for important crops in the Sultanate under existing climatic conditions, soil and water quality in different regions.

2. Estimating crop water requirements associated with the important crops, soil and water quantity and quality, which helps to improve the investment of water resources in agriculture in the Sultanate.
3. Conducting research to assess the soil fertility and determine fertilizer rates according to the nutritional needs of plants.
4. Conducting research on diversified crops, vegetables and fruits by way of :
 - i. The introduction of new varieties.
 - ii. Introduction of new technologies in agriculture, such as plastic houses, hydroponics agriculture.
 - iii. Formation of appropriate crop constellations for each agro-ecological region.
 - iv. Study the impact of agricultural practices on production and quality of crop produce.
 - v. Introduction of new varieties of wheat and barley, and other field crops.
 - vi. Evaluation and preservation of agricultural products, especially dates.
 - vii. Conduct studies and research to combat pests and diseases and methods of integrated management to rationalize the use of pesticides and maintain a clean environment free from pollution.
 - viii. Conduct research on the safety intervals between spraying and harvest of crops to maintain crop residues at safer levels for the health of farmers and consumers and monitor the quality of pesticides used.
 - ix. To conduct research and studies related to salinity and water scarcity and their impact on the productivity of agricultural crops.
5. Genetic improvement of local breeds of livestock (cows, goats, sheep, poultry) in the Sultanate and vaccination for epidemic diseases.
6. Conservation of the biodiversity of plants and animals, and natural resources management.
7. Conducting research on treatment of livestock against existing and introduced endemic and epidemic diseases.

The Sultanate of Oman is well aware of the importance of not only its agriculture resources like indigenous plant genetic resources for food and agriculture, which contribute to food security but also of its water and animal resources for sustainable development of agriculture. Towards attaining sustainable agriculture, Oman grows the crops of environmental and economic importance in its traditional sustainable agriculture like dates, Omani lime and alfalfa and rear indigenous livestock animals like sheep, goat, cattle, camel, poultry birds etc. Several research and developmental programs in the country contribute to conservation and management of both food and agriculture crops and animals. These programs are related mostly to improvement of indigenous cultivars of strategic crops and animal and poultry breeds through conventional and non-conventional breeding methods for high yield and disease/pest tolerance.

The indigenous crops of Oman, such as wheat, barley, chickpea, dates, and lime with traditional food value are cultivated in almost all regions of the country. Oman considers them as strategic crops for food security as they form the base of Omani diet. Similarly, Oman also considers sheep and goat as strategic animals for meat production. Hence, Oman is committed to maintain the local cultivars of these crops and local breeds of sheep and goat, which have an immense value for the future. Conserving diversity of crops and animals is of utmost importance, as it allows breeders to take advantage of adaptive traits present in this diversity and develop improved cultivars that are able to respond to changes in the environment. This is essential to meet the growing demand of food, in terms of both quantity, and quality, coming from this country as well as the world as a whole.

6. DEVELOPMENT STAGES OF AGRICULTURE AND LIVESTOCK RESEARCH

The first agricultural research station was initiated in Nizwa in the Interior in 1959. Subsequently, several research stations were initiated throughout the country. Agriculture research in the Sultanate underwent several development stages gradually until recently completion of all the infrastructures and research equipments of international standard along with the library, under the Directorate General of Agriculture and Livestock Research (DGALR). The DGALR consists at present six research centers viz. Plant Production Research Center, Plant Protection Research Center, Soil and Water Research Center, Date Palm Research Center, Livestock Production Research Center and Veterinary Research Center, each consisting of different labs. Besides, ten experimental stations, three of these stations belonging to livestock research and four research farms are distributed in most regions of Sultanate, under the umbrella of DGALR (Appendixes 1 and 2). The research centers and stations are responsible to conduct scientific experiments on plant production and protection, date palm research comprising horticulture, tissue culture and biotechnology and food processing, soil and water as well as research studies on livestock production and veterinary.

DGALR human capacity consists of 496 employees (including the ones with contract) till the end of December 2010. There are 5 experts, 12 Omanis Ph.D., 17 Ph.D. students, 19 M.Sc., 6 M.Sc. Students, 70 B.Sc., 5 B.Sc. students and 13 Diploma, in addition to research technicians, administration and finance staff as well as agriculture workers (Appendix 3).

7. ACHIEVEMENTS OF AGRICULTURE AND LIVESTOCK RESEARCH IN THE PREVIOUS PLANS (2000 TO 2010)

- i. Recommendation of selected promising new varieties of vegetable crops, horticulture crops and field and forage crops for general cultivation.
- ii. Development of cereal crops in particular towards increasing the productivity of wheat within the purview of food security since last four decades through introduction, evaluation

and selection of high yielding superior quality wheat lines/ genotypes .The most important varieties released are Wadi Quriyat Selections (WQS) are WQS-110, WQS-101, WQS- 126, WQS-151, WQS-302.

- iii. Improvement of local wheat and barley.
- iv. Selection of high yielding forage pearl millet and sorghum varieties under moderately high saline water conditions.
- v. Development of new technological packages of crop husbandry, planting dates, fertilizer application, methods of planting etc for important vegetable, fruit and field crops.
- vi. Development of modified plastic houses and soil less culture techniques for growing vegetable crops commercially.
- vii. Establishment of Field Gene Bank (*Ex-Situ*) of pastoral and medicinal plants in the Agricultural Research Station, Al-Rumais which contains 244 species of herbaceous plants, shrubs.
- viii. Development of new seed production techniques and seed harvesting in perennial grass species like Rhodes grass (*Chloris gayana*) and Buffel grass (*Cenchrus ciliaris*).
- ix. Determination of the actual water needs of the most important agricultural crops such as Date palm, tomatoes, melon, cucumber, Rhodes grass and alfalfa.
- x. Application of integrated production and protection management (IPPM) of pests and diseases for the cultivation of vegetables in greenhouses using alternative methods of application of chemical pesticides.
- xi. Recommendation of the treatments of honeybees against diseases to preserve the indigenous species and the development of specifications for the bee-hives.
- xii. Study characteristics of milk production of foreign breeds namely Jersey, Friesian, Kinanah under Omani conditions to compare these characteristics with that of indigenous breeds.
- xiii. Introduction of foreign breeds of goats, sheep and cows for adaptability under Omani conditions and cross breed with indigenous breeds for producing highly productive offsprings in terms of meat and milk production.
- xiv. Distribution of improved bulls and F1 hybrids among the farmers for producing highly productive offsprings in terms of milk and meat.
- xv. Promotion of domestic poultry in Dhofar.
- xvi. Contribution to Control of various epidemic animal diseases and the prevention of transboundary diseases in animals.
- xvii. Laboratory Analysis of more than 70 thousand samples from different plants, soil, water, agro-chemicals, and animals including poultry.
- xviii. Laboratory diagnosis of many diseases in animals and poultry birds, and recommending programs to ensure to limit their spread and control.

8. SUCCESS STORIES

- i. Extensive spread of greenhouse technology to grow the vegetables crops like cucumbers, tomatoes, sweet pepper and melons using soil and under hydroponics (soilless growing technique) throughout the Sultanate. The outstanding results indicated that cucumber produced 11 tons/ 648 m² of cucumber and 2.5 tons/ 270 m² of tomatoes under greenhouse conditions. This technology reduced water consumption by about 20 to 30% and raised the productivity to 60% and 30% more than that under open field conditions, respectively, in case of cucumber and tomato. This technology ensures quality produce, enhances their availability in the market in off-times and rewards the income of farmers to contribute to food security in the country.
- ii. Dissemination of vertical farming technology under hydroponics to grow crops such as strawberries and lettuce.
- iii. Establishment of a tissue culture laboratory in 1992 (Jimah Research Station) in Interior Region has led to mass propagation of more than ¼ million date palm offshoots and distribution among the farmers to replace old or dead trees.
- iv. Integrated Pest Management (IPM) Program including biological control has been successfully applied to control pomegranate butter fly (*Virachola livia*) by releasing annually about 300 millions of *Trichogramma* parasitoid in villages of Al-Jabal Al-Akhdar. This has given excellent results not only in reducing the economic damage but also in achieving attractive economic returns of the farmers to the extent of about one million Omani Riyals annually.
- v. Several research studies of insecticides trials in Dubas bug IPM program have been successful in reducing the Dubas bug infestation in the infested areas.
- vi. Several surveys have been conducted have indicated that the country is free from the serious pests and diseases such as Panama disease in banana and black stem rust (Ug99) in wheat.
- vii. The containment measures of red palm weevil have succeeded in controlling the pest within the infested areas (Mussandam, Al-Buraimi, Al-Dhahirah and Al-Batinah).
- viii. Dissemination of modern irrigation technologies (drippers, bubblers, sprinklers) and the research outcomes of increasing water-use efficiency, have contributed in saving irrigation water.
- ix. Studies conducted at Agricultural Research Station, Rumais from 2004 to 2010 and a pilot project undertaken in Saham from 2008 to 2010 in collaboration with Liquefied Natural Gas Co. (LNG) and Ministry of Regional Municipalities and Water Resources (MRMWR) proved that use of treated wastewater (TWW) could be feasible for use as an alternate source in the cultivation of sorghum, barley and maize for fodder and wheat for seed.
- x. Several seed production studies between 2000 and 2005 had clearly demonstrated for the first time that seed of indigenous pasture species like *Cenchrus ciliaris* could be produced in the hot arid climate throughout the year to re-vegetate degraded rangelands of Oman.

- xi. The distribution of more than 100 selected rams of sheep and goats from Wadi Quriyat Livestock Research Station to farmers has contributed for the improvement of the local breeds.
- xii. Effective control of Equine disease epidemics
- xiii. Concerted efforts have ensured the country free from several transboundary animal diseases such as Avian influenza, Rift Valley fever, West Nile fever.
- xiv. Containment of several livestock and zoonotic diseases such as Brucellosis, Rabies, Foot and mouth disease and screw worm, through prompt diagnosis.

9. FIVE-YEAR AGRICULTURE AND LIVESTOCK RESEARCH STRATEGY- 2011 TO 2015

Omani agriculture is suffering from both abiotic and biotic problems since couple of decades in addition to climate change which has recently caused an impact on agriculture. Abiotic problems include water stress throughout the country and salinity all along the coastal regions due to prolonged drought while biotic problems have been associated with severe attacks of pests on major horticulture crops of the country like Dubas bug in date palm, witches-broom on Omani lime, fruit fly in pomegranate and decline of mango trees. Right from the beginning of 21st Century, agriculture research witnessed multitude of activities leading to solutions to problems related to production and protection in the cultivation of important crop plant species, their post harvest technology and food processing. There are also activities on successful cultivation of vegetables such as tomato, cucumber, strawberries etc. in plastic houses involving different growing techniques and cooling systems, the activities concerning optimal soil and water management, combating issues about water stress and soil and water salinity, and conservation of indigenous pasture plant species to improve degraded native rangelands. In livestock also there are problems of production and protection in husbandry of goat, sheep, cattle, camels and poultry birds and conservation and improvement of their indigenous breeds. Furthermore, there are also issues related to both endemic and epidemic diseases like Theileriosis in sheep, goats and cattle and Avian Influenza in poultry birds etc. for diagnosis and safe treatment.

The DGALR aims at national level to undertake both basic and applied research in agriculture and livestock industries. Its objective is to solve the problems faced in agriculture and livestock husbandry besides increasing in the crop and livestock production that in turn uplift socio-economic status through sustainable agriculture for food security. In addition, these researches aim to conserve the environmental resources like water and soil, and plant and animal genetic resources. In line with its objectives, the DGALR has formulated its Five Year Research Strategy from 2011 to 2015 with following Vision, Mission and Goals.

9.1. VISION

Enhancement of agricultural and livestock sectors to support food security along with plant and animal genetic resources management, continued rehabilitation and construction of research infrastructure and capacity building and human resources development in collaboration with national stakeholders and international organizations.

9.2. MISSION

- Plan agricultural and livestock research programs according to the priorities adopted for the development of the agricultural and livestock sectors and find the most suitable solutions.
- Update research that serve the agricultural sector and livestock development in the Sultanate of Oman, that helps to support food security and social community with the conservation of biological diversity and optimum management of natural resources.
- Participate in implementing the national strategy for the advancement of agricultural crops like date palm and wheat and livestock animals like goat and sheep of national significance.
- Conduct applied research in both the agricultural and livestock sectors which are socio-economically viable.

9.3. GOALS

- Increase productivity of major crops: date palm, lime, wheat, etc.
- Increase productivity of the main vegetables and fodder crops.
- Use of methods of breeding and genetic improvement to increase the productivity of agricultural crops and livestock.
- Use of advanced technologies such as biotechnology to improve the productivity of agricultural crops and livestock.
- Conservation and management of biodiversity and genetic resources to ensure their sustainability.
- Improve water-use efficiency of crops.
- Use non-conventional irrigation water resources like saline water and tertiary treated wastewater in agricultural production, particularly for growing fodder crops, trees and pastoral shrubs.
- Control pests and diseases of major field, vegetable and horticulture crops.
- Control pests and diseases of livestock animals such as goat, sheep, cattle, camel and poultry.
- Undertaking studies on the social and economic feasibility of the research projects.

10. MEGA-PROGRAMS (MPS)

The agriculture and livestock strategy (2011-2015) comprises ten Mega-programs with different research projects keeping in view of their national importance and significance in contributing to support long-term economic and social development within the Five-Year National Plan-2011-2015, as follows:

MP 1. Date Palm Research Program

- i. Integrated management of date palm pests and diseases
- ii. Integrated pest management of Dubas Bug and Red palm weevil
- iii. Improvement of pre-harvest treatments of dates
- iv. Improvement of post-harvest treatments of dates
- v. Valorization of industrial dates value
- vi. Molecular genetic diversity of date palm

MP 2. Water-Use Efficiency (WUE) and Irrigation Management Program

- i. Improvement of WUE under protected agriculture & soilless techniques
- ii. Optimization of water- use and management under various environments

MP 3. Plant Genetic Resources Management and Improvement Program

- i. Collection, conservation and documentation of indigenous crop/ plant species and rangeland germplasm
- ii. Utilization of indigenous and exotic crops and rangeland germplasm in agriculture production
- iii. Monitoring health and quality of seed and vegetative propagation material

MP 4. Improvement of Animal Genetic Resources and Management Program

- i. Genetic improvement of indigenous cattle, small ruminants and poultry
- ii. Conservation of indigenous genetic resources for sustainability
- iii. Production of concentrate feeds exploiting local resources

MP 5. Integrated Production and Protection Management Program

- i. Survey and identification of pests and diseases of major cultivated crops
- ii. Safe-use of conventional and eco-friendly agrochemicals
- iii. Optimization of plant nutrition requirements
- iv. Identification and utilization of plant associated soil microorganisms
- v. Development of sustainable pest management approaches
- vi. Identification and management of honey bee pests and diseases
- vii. Biological and ecological studies of major pests & diseases

MP 6. Biological Control Research and Development Program

- i. Survey and identification of indigenous natural enemies
- ii. Mass multiplication and utilization of efficient biological control agents

MP 7. Food Safety and Quality Research Program

- i. Physical and chemical characterization of Omani dates
- ii. Evaluation of Omani honey for quality
- iii. Assessment of antibiotic residues in animal products
- iv. Assessment of pesticide residues in agriculture products

MP 8. Non-Conventional Water use Program for Agriculture Production

- i. Safe-use of treated wastewater in agriculture production
- ii. Utilization of saline water for sustainable agriculture

MP 9. Surveillance of Livestock Epidemics and Transmitted Diseases

- i. Surveillance and monitoring of emerging and re-emerging diseases
- ii. Patho-biological studies of animal diseases

MP 10. Supportive Services

- i. Production of tissue culture date palm seedlings
- ii. Production of improved fruit trees seedlings
- iii. Diagnosis and field investigations of plant and animal pests and diseases
- iv. Laboratory analysis of soil, water, plants and agro-chemicals
- v. Capacity building (students' training, On-job training, field visits, field days, workshops and conferences).

The above projects of the mega-programs have been developed based on the following principles:

- Liability: Adoption of the principles of responsibility in terms of programs and activities of agricultural and livestock research
- Scientific integrity and transparency
- Provide an appropriate environment that offer opportunities for innovation and development and personal ambition
- Working in the spirit of the research team
- Reduction of interference and duplication
- Community service to ensure the goals and objectives of the community and preserve the agricultural environment

The following are details of each research project of the mega-programs along with brief rational, objectives and expected outcomes.

MP 1- DATE PALM RESEARCH PROGRAM

Project 1.1. Integrated Management of Date palm Pests and Diseases

Rational:

Date palm is the main economic crop in Oman. In fact it plays a major role in the social life of Omani people and in conserving the bio-eco system. Pests and diseases pose important threats to the productivity and existence of date palm. Of major importance are Dubas bug (*Ommatissus lybicus* De Bergevin), Red palm weevil (*Rhynchophorus ferrugineus* Oliver) and Lesser date moth (*Batrachedra amydraula*) and decline associated with fungi complexes. Survey for identification and monitoring the occurring and the emerging pests and diseases as well as biological, ecological and management studies of the most economical threats are vital to resolve constraints limiting date palm trees qualitative and quantitative production.

Objectives:

- To screen date palm varieties for tolerance/ resistance to pests and diseases.
- To develop integrated sustainable management practices.
- To minimize risks/ contamination to environment from misuse of pesticides.

Expected Outcomes:

- Conservation of date palm plantations and natural bio-ecosystem.
- Development and application of good production and protection practices.

Project 1.2. Integrated Management of Dubas bug and Red Palm Weevil

Rational:

Dubas bug (*Ommatissus lybicus* De Bergevin) is a major pest of economic importance, affecting growth and yield of date palms quantitatively and qualitatively. It is a serious sucking insect pest in the Sultanate of Oman. Since it's recording in 1962, the Ministry of Agriculture is concerned every year to manage the Dubas bug infestation, by aerial and ground application of selected insecticides in a date palm plantation area of about 30 thousand Acers. Several insecticide efficacy experiments were conducted over the last few decades for Dubas bug control on infested villages in Oman Two parasites (*Oligosta* sp. & *Bocchus hyalinus*) were recorded in the Sultanate on different stages of Dubas bug.

Red palm weevil *Rhynchophorus ferrugineus* Oliver is considered as a destructive pest of several palm species where date palm is among them. Damage is caused by extensive tunneling of larvae in the trunk, which weakens palm tree due to tissue collapse and finally date palm tree breaks

easily and dies eventually. The pest was first discovered in 1993 in Mahdha and Buraimi Wilayas and then subsequently reported in the Governorate of Musandam followed by the Wilayats of Shinas, Sohar, Saham and Al-Khabora of Al-Batanah region and Yanqul and Dank Wilayas of Al-Dhahira region.

Objectives:

- To develop integrated sustainable Dubas bug and Red Palm Weevil management practices.
- To develop and promote an Integrated Dubas bug management strategy.
- To reduce economical damage of Dubas bug and eradicate introduced RPW on date palm trees.
- To reduce the reliance on broad spectrum insecticides by establishing safe and effective alternatives.
- To enhance the both infrastructure and human capacity for IPM development.

Expected Outcomes:

- Renewal of knowledge about the reasons of variation of infestation level and infestation cycle of *Dubas bug (O. lybicus)* on date palm.
- Prediction of the critical insect stages and the appropriate time for improved Dubas bug and RPW management.
- Development of database and early warning prediction for Dubas bug and Red Palm Weevil in all date palm growing areas
- Identification of the efficient indigenous bioagents on *O. lybicus*.
- Establishment of appropriate techniques for mass production and augmentation releases of indigenous parasitoids especially *Oligosita sp.*
- Enhancement of the natural enemies interaction efficacy in managing *O. lybicus* and RPW.

Project 1.3. Improvement of Pre-harvest Treatments of Dates

Rational:

Date palm is one of the major crops of Oman that contributes to the national economy. There have been records of significant losses of date yield by premature falling of fruits, formation of abnormal or subnormal shapes/ sizes of fruits etc. prior to harvest of the fruits. In order to reduce, pre-harvest losses, several studies have been conducted or in progress not only in Oman but also in all date growing countries, that aimed to improve both yield and quality of dates such as thinning of branches and fronds, methods of harvesting, use of pre-harvest sprays of hormones, chemicals, organic fertilizers etc. to flowers/ fruits to induce or delay maturity to meet the demand of date consumers.

Objectives:

- To improve growth and fruiting of date palm trees.
- To increase per unit date yield for improving farmers economy.
- To improve the market quality of different date products ("*rutab* and *tamar*") suitable for domestic consumption and export.

Expected Outcomes:

- Improvement of date palm husbandry practices.
- Improvement of date palm national returns through producing export quality dates/ products.
- Improvement of date growing farmers' income.

Project 1.4. Improvement of Post-harvest Treatments of Dates**Rational:**

The storage of dates under low temperature conditions is crucial to extend the shelf life of the date fruits and to obstruct the infestation. However, the applied low temperatures could cause some changes in the physical as well as chemical properties of the fruits. The temperature degree will be the main factor that produces these alterations. It is therefore very important to determine the right temperatures, which maintain the quality of the fruit, and prevent the infestation and deterioration.

Nowadays, many fruits and vegetable are stored under dormant gas mixtures to delay repining and to extend the shelf life. In addition, these kinds of storage ensure the quality as well as the freshness of the stored produce. Applications of ethylene blocker have been found as important factor in slowing the over ripening of the fruits during transportation and storage. Since these treatments have been not thoroughly investigated on dates the proposed work will cover this important issue for the quality and marketing of the date fruits.

Objectives:

- To determine the optimal storage conditions of the common Omani cultivars.
- To characterize the alteration in the chemical and physical properties of the common cultivars by the applied temperatures.
- To preserve the quality of the harvested dates throughout handling and storage.
- To extend the storage life of *biser* and *rutab* stage.
- To understand the effect of the ethylene blocker on the quality attributes of dates with different concentrations of gases.

Expected Outcomes:

- Improvement of Omani date's quality.
- Elevation of the export opportunities to the promising markets.
- Enhancement of the produce turnover as well as growers income.

Project 1.5. Valorization of Industrial Dates Value**Rational:**

The annual statistics of MoA shows almost half of the date's production is neither consumed by the local population nor exported. These numbers have adverse effect on the date's economy through devaluing of the produce. Since the dates contain high percent of invert fermentable sugar the production of some valuable ingredients such as citric acid, liquid sugar and high fructose syrup can be obtained through biotechnological techniques as well as physical-chemical techniques. However, the date's juice as raw substrate for such industries requires intensive investigation to apply successfully. Based on previous works, the isolation and purification of the derived products needs to be distinctively developed.

Objectives:

- To utilize the date's surplus and low quality fruits.
- To investigate the dates juice of different cultivars as raw material for sophisticated industries.

Expected Outcomes:

- Utilization of dates as local raw materials for feasible dates industry.
- Realization of technology transfer by the end of the bench type research and proceeding to the proposed pilot plant phase.

Project 1.6. Molecular Genetic Diversity of Date palm**Rational:**

Genetic diversity of the Omani date palm cultivars is very important for both research and agricultural application. Several studies have been conducted in date palm to know the extent of genetic diversity among the date palm cultivars and identify the genetic relationship between them. Most studies focus on identifying the cultivars by using a wide range of morphological and chemical characters, which are highly influenced by environmental conditions and might not reflect the true genetic relationships. Recently, DNA-based techniques have been developed and have proved effective to assess genetic diversity and fingerprinting of palm species. Microsatellites or SSRs (simple sequence repeat) is one of the DNA informative polymorphic marker systems.

Fingerprinting is used for accurate identification of cultivars and registration of the new cultivars for the Plant Variety Protection (PVP). It also shows the genetic variations within the cultivar. To date, thirteen Omani date palm cultivars (Khalas A'Dhahira, Khalas Oman, Fardh, Naghal, Khasab, Bahlani female, Bahlani male, Khenazi, Bo'hbasha, Bunaringa, Khorī male, Thameed, Zabad) have been characterized.

Objectives:

- Molecular characterization of date palm cultivars.
- Comprehend genetic diversity and relationships between and within date palm cultivars.

Expected Outcomes:

- Molecular identification of date palm cultivars.
- Register the Omani cultivars under national law and international convention.

MP 2. WATER-USE EFFICIENCY (WUE) AND IRRIGATION MANAGEMENT PROGRAM

Project 2.1. Improvement of WUE under Protected Agriculture and Soilless techniques

Rational:

Greenhouses are widely spread out recently in Oman. In addition to protecting the plants and controlling the micro-environment, they maximize the production even by vertical expanding and exploiting unfavorable seasons by controlling the micro-environment and conserving water by means of using modern irrigation systems. Since water is a limiting factor in expanding irrigated agriculture, because of their limited resources and misused by farmers. There is a lack of information dealing with crop water requirements and irrigation scheduling under greenhouse conditions for the main vegetable crops in Oman except for cucumber and sweet pepper. It has been found that a 270 m² greenhouse cucumber requires 46-53 m³ water/season. When farmers apply excess water they in fact leach fertilizers beyond the root zone to reduce their benefits to the plant benefit or reduce the respiration rate or even plant death due to water logging. There is a need for relating the different amounts of water applied to the plant yield parameters. Maximum water-use efficiency is achieved by applying certain amount of water to the plants to increase the productivity of the crop.

Objectives:

- To estimate the water requirements and water use efficiency of greenhouse vegetable crops.
- To make irrigation scheduling for improving the water productivity.
- To determine the relationship between the different amounts of irrigation water applied and the yield parameters under greenhouse conditions.

Expected Outcomes:

- Improvement water use efficiency.
- Determination of irrigation production function.
- Proposal of Irrigation scheduling to farmers.
- Reduction of ground-water demand.
- Planning of effective cropping pattern according to water productivity.

Project 2.2. Optimization of water-use and management under various environments

Rational:

Water is a limiting factor for expanding irrigated agriculture in Oman, because of its limited resources, which is often misused by farmers as they apply more water than the crop needs. Hence, appropriate water requirements of crops are very important and essential in irrigation scheduling. The results of previous studies of water requirements or consumption have indicated that date palm consumes $32870 \text{ m}^3 \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$, and greenhouse cucumber consumes $46\text{-}53 \text{ m}^3 / \text{season}$ spanning 120 days/greenhouse (270m^2). Rhodes grass requires $22438 \text{ m}^3 \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$ and watermelon requires $3158 \text{ m}^3 \cdot \text{ha}^{-1}$. Sweet pepper consumes $6500 \text{ m}^3 \cdot \text{ha}^{-1}$ and muskmelon consumes $1270\text{-}1455 \text{ m}^3 \cdot \text{ha}^{-1}$, elsewhere in the world. However, there is a lack of information dealing with crop water requirements and irrigation scheduling for the most priority crops in Oman with respect to Oman conditions. We know that excess water may leach fertilizers beyond the root zone and reduces their benefits to plants or reduce the respiration rate or even plant death due to water logging. There is a need for relating quantity of water applied to the growth and yield parameters. Maximum yield potential of the crop is achieved by applying optimum quantity of water to the plants that are suitable for their growth and respiration. Due to over pumping of water and effects of prolonged drought since couple of decades, ground water has been gradually deteriorated and turned saline due to seawater intrusion in most of the coastal plains in Oman. In view of the above water situations, there is need for optimization and management of irrigation water under both normal and saline water environments.

Objectives:

- To estimate the water requirements and water- use efficiency of crops.
- To schedule irrigation for improving water productivity.
- To determine the relationship between the different amounts of irrigation water applied. yield and quality parameters.

Expected Outcomes:

- Application of the relationship between soil, plant, water, and atmosphere for different crops.
- Improvement of water use efficiency of crops.
- Application of the improved Irrigation scheduling.
- Reduce the leaching of fertilizers below the root zone.
- Increasing the return per unit of used water within improved cropping pattern.

MP 3. PLANT GENETIC RESOURCES MANAGEMENT AND IMPROVEMENT PROGRAM

Project 3.1. Collection, Conservation and Documentation of Indigenous Crops / Plant Species and Rangeland Germplasm

Rational:

Oman has a wide diversity of crop plants for food or feed purpose in addition to other human use. Among the important crop plant species are 12 field crops, 7 vegetables, 11 fruit trees, 20 forest trees and more than 100 rangeland pasture species and a few aromatic and medicinal plant species that are known to be grown in the Sultanate since time immemorial. Oman has not only several locally adapted cultivars and land races of crop species but also unexplored crop wild relatives (CWR) that may be an irreplaceable source of diversity for traits useful for crop improvement. There are evidences of an increasing pressure on this diversity from several factors, among these, soil and water salinity, drought, scarcity of irrigation water, and high grazing pressure by increased number of livestock. These factors are inevitably posing a serious threat to the very survival of Omani indigenous crop species, varieties and wild relatives, which need to be conserved and documented.

Collection missions of indigenous plant genetic resources were undertaken by the Ministry of Agriculture during 1980s in collaboration with the International Bureau of Plant Genetic Resources. Further missions were conducted in late 1990s and early 2000 with international institutes like the International Center of Agriculture Research in Dry Areas (ICARDA) and the International Center of Bio-saline Agriculture (ICBA). More than thousand of these accessions currently have been conserved in International centers such as ICARDA and national institute such as USDA. These accessions need to be repatriated and subjected to conservation and documentation using database management system with modern tools like Global Information System (GIS) and satellite imagery, in the country.

There are numerous activities towards conservation of local landraces of vegetable crops such as onion, garlic, cucumber, sweet potato etc. and grain crops such as wheat, barley, chickpea etc. through on-farm management since early 1990s in addition to selected local and exotic fruit tree crops like date palm, Omani lime, banana etc. are being multiplied through tissue culture for distribution among the farmers.

Objectives:

- Collection of indigenous food, fruit and forage crop varieties/ wild relatives and plant species of economic importance like medicinal and aromatic plants.

- *Ex-Situ* gene conservation of all the collected PGR.
- Seed / seedling multiplication / production and seed / seedling tests of quality and purity.
- Characterization of important/ selected PGR material from the collections.
- Documentation of relevant collection, characterization and evaluation data.

Expected Outcomes:

- All the collected material of indigenous food (field crops & vegetables), fruit and forage crop varieties/ CWR and plant species of economic importance like medicinal and aromatic plants -conserved in national gene bank.
- Up-to date documentation of relevant collection, characterization and evaluation data.
- Establishment of *Ex-Situ* gene banks and In-Situ conservation of germplasm and / or crops of national importance.

Project 3.2. Utilization of Indigenous and Exotic Crops and Rangeland Germplasm in Agriculture Production

Rational:

Oman is fully aware of the importance of utilization of its indigenous plant genetic resources for food and agriculture. Since 1990's, activities have been started for introduction, selection and improvement through traditional breeding, as well as biotechnology and tissue culture techniques of indigenous germplasm like dates, mango, banana, sweet-lime, acid-lime, cucumber, barley, alfalfa and pasture plant species. Ministry of Agriculture has so far introduced many field, vegetable and fruit crop species and released more than 100 varieties through evaluation and selection accordingly under open field, plastic houses, soilless, hydroponics conditions using appropriate irrigation systems. Improvement of indigenous cultivars of wheat, barley and date palm through selection and plant breeding have been started a decade before which resulted in more than ten promising selections with character combinations of high yield, quality and resistance. Among the large collections of indigenous rangeland germplasm in Oman, those accessions having economic value would be used for their further exploitation. For instance, valued indigenous rangeland species having forage value could be introduced in the domestic cropping/ crop production systems for cultivation as perennial forage as in case of *Cenchrus ciliaris*, which is under farmers' trial under Arabian Peninsula Research Program of ICARDA. Indigenous rangeland species of medicinal value could be exploited in agriculture for their utilization in industrial medicine and those indigenous species of aromatic and medicinal value can be utilized in both aromatic and medicinal industries. Important indigenous crop cultivars/ ecotypes need to be improved for traits of interest such as resistance/ tolerance to serious abiotic (drought and salinity) and biotic (diseases and pests) stresses. Basic and foundation seed multiplication / production of released varieties is very much an extension of the breeding adopting improved seed production and processing techniques.

Objectives:

- Screening and evaluation of cultivars/ varieties of field/ vegetable / fruit tree/ forage crops for yield, quality and resistance / tolerance to biotic and abiotic stresses under field conditions.
- Screening and evaluation of varieties of vegetable crops under plastic house soilless / hydroponic conditions.
- Improvement of indigenous crops through conventional or non-conventional breeding techniques for higher productivity, quality and / or tolerance to biotic/ abiotic stresses.
- Utilization of indigenous/ exotic/ crop or plant species to accommodate in existing cropping / production systems or for industrial use (medicinal or aromatic).
- Seed / seedlings multiplication / production and tests of quality and purity.

Expected Outcomes:

- Release and recommend promising genotypes selected for higher yield, quality and resistance for general cultivation under field/ plastic house/ soilless and /or hydroponic conditions.
- Development of new breeding lines/ genotypes for higher yield / quality/ resistance.
- Introduction of indigenous/ exotic plant / crop species in existing cropping/ production systems.
- Streamlining of seed production techniques / seed quality / purity for prioritized crops.
- Distribution of improved crop variety seed among the farmers.

Project 3.3. Monitoring Health and Quality of Seed and Vegetative Propagation Material

Rational:

Proper conservation and utilization of plant genetic resources is vital to ensure food security. Seeds and vegetative plant parts are propagating materials and are considered as major sources for plant pest dissemination. Seed-borne pathogens, such as fungi, bacteria and viruses are serious constraints to crop productivity. In some cases they can be disastrous and even life threatening such as ergot disease of cereals. Additionally, it's the major factor affecting the production of quality seeds. The losses are ensued not only during seed development but also during planting and storage. Seed-borne diseases may impede the proper utilization of plant genetic resources through loss of germplasm due to death of seed and seedling, as well as spread of seed-borne diseases in the field and across, national or international boundaries. To reduce the losses, seed borne and seed transmitted diseases require early detection. The increase in international trade of propagation material has led to the rise of phyto-sanitary issues. Hence, seed health testing is essential. For management of seed borne & seed transmitted diseases, seed treatment falls into two categories: thermal or chemical. Identification, detection methods & records for fungal pathogens have been developed. However, for bacterial & viral pathogens, it is not fully

developed and those pathogens can still escape detection with the conventional assay methods. Serological and DNA-based assays are the new techniques used to detect and identify seed borne and seed transmitted diseases.

The yield and economic success of crop species depends to a large degree on the quality of the seed used to grow these crops. High quality seeds are undamaged seeds that have a high level of germination, which will produce uniform, vigorous seedlings without defects under various environmental conditions. Seed quality attributes include dormancy, germination (rate and uniformity), seed and seedling vigour (germination/growth under stress conditions), seedling dry weight, normal embryo- and seedling morphology, as well as the ability to develop into a normal plant. Seed quality is largely established during seed development and maturation, as a result of, often complex, interactions between the genome and the environment. Testing for physical purity and viability of seeds are the two most important tests needed to avoid weed problems and poor stand establishment. Other seed quality tests such as vigor tests, x-ray, and seed moisture content provide useful information about the quality of the seeds.

Objectives:

- Detection and identification of seed borne and propagation material transmitted diseases.
- Monitoring of local and imported material for seed borne & transmitted diseases.
- Testing of seed purity and quality.

Expected Outcomes:

- Proper conservation and utilization of plant genetic resources.
- Complete and comprehensive data on different seed borne and propagation material transmitted diseases.
- Enhanced seed health and quality management tools.

MP 4. IMPROVEMENT OF ANIMAL GENETIC RESOURCES AND MANAGEMENT PROGRAM

Project 4.1. Genetic Improvement of Indigenous Cattle, Small Ruminants and Poultry

Rational:

Genetic improvement for indigenous livestock based on a clear selection program is the main goal of Livestock Research Center. In 1990, a program was started in Wadi Quriat research station to improve the Omani sheep and goat breeds and in Salalah Research Station; another program was established to improve the local poultry breeds. The selection activity was started to improve the local cow breeds in 1994 to improve the southern breed and in 2003 to improve the north cow breed.

Objectives:

- Improve the productive and reproductive traits for indigenous livestock breeds in Oman.
- Conservation and sustentation of indigenous livestock breeds which are at risk (*Ex-Situ* and *In-Situ*).

Expected Outcomes:

- Disseminate the improved males from different breeds to the farmers.
- Register the local Omani livestock breeds according to the national law.
- Enhance milk, meat and egg production for the small-scale breeders.

Project 4.2. Conservation of Indigenous Genetic Resources for Sustainability

Rational:

Phenotypic characterization of the breeds is the first step in planning a national genetic improvement scheme. Most of livestock breeds in Oman are raised with the smallholders under the traditional system. In 2003 the research work began at Livestock Research Center with aim to identify and classify the small ruminant breeds of north of Oman. In July 2010, the artificial insemination laboratory was established to collect, preparing and distributing the high quality semen from southern and northern local cow breeds. This lab will be a nucleus for establishing the livestock gen bank.

Objectives:

- Classification and Identification of indigenous livestock breeds.
- Determine the genetic makeup of the indigenous small ruminant breeds.
- Conducting the progeny test for local males.

- Produce the high quality semen from local and imported improved bulls.

Expected Outcomes:

- Provide semen straws from the improved males to the artificial insemination units of MoA.
- Genetically improved bulls available for distribution among the farmers.

Project 4.3. Production of Concentrate Feeds Exploiting Local Resources

Rational:

The research work in the field of animal nutrition concentrates recently on inventory and analysis of the local raw materials that utilized in animal feeds. During the period from 1989 to 2004 different scenarios of producing the feed mixture was done by using local raw materials from agriculture, industrial and fish by-products. In May 2010, a manufacturing research unit was installed to produce animal feed concentrate for intensive exploitation of local raw materials.

Objective:

- To produce concentrated animal feeds utilizing local products and residues of agricultural and industrial by-products.

Expected Outcomes:

- Reduce the production cost of concentrated animal feeds.
- Conserve the environmental background form the agriculture and industrial wastes.

MP 5. INTEGRATED PRODUCTION AND PROTECTION MANAGEMENT PROGRAM

Project 5.1. Survey and Identification of Pests and Diseases of Major Cultivated Crops

Rational:

A number of pests and diseases have risen as a result of the favorable environment available in the different cultivation systems and are considered as constraints facing the productivity and sustainability of agriculture in Oman. The introduction risk of severe diseases e.g. Panama disease *Fusarium oxysporum* on banana and Ug99 in wheat may cause serious threat. Extensive surveys have been conducted and documented for the pests and diseases associated with crops in the northern and southern parts of Oman. Surveys have to be continued to monitor prevalent and newly emerging pests and diseases. Protected agriculture (shade houses, closed and open soil/soilless cultures and hydroponic cultures) as well as open field crops have to be monitored in order to sustain the judicious use of advanced and efficient control measures protecting the limited resources.

Objectives:

- To assess the effect of pests and diseases on the prevalent crops under various cultivation systems.
- To assess the risk of newly introduced pests and potentially damageable ones.
- To develop sustainable eco-friendly approaches for pest and diseases management.

Expected Outcomes:

- Valid identification and documentation of prevalent and emerging pests and diseases.
- Recommendation of proper short and long term management approaches/ strategies.
- Minimize losses due to pests and diseases.

Project 5.2. Safe-Use of Conventional and Eco-Friendly Agrochemicals

Rational:

The adverse effects of agrochemicals to human health and environment are a serious concern in Oman. The extensive use of pesticides could lead to the development of resistance in the targeted pests and disease causing organisms. Besides, the introduction of newly developed pesticides requires the test of their efficacy. Since 1980's, many agrochemicals are evaluated and recommended to the end users. Research should be strengthened for testing eco-friendly substitutes to the conventional products. Both conventional and eco-friendly agrochemicals should be screened through laboratory (toxicology, bioassay etc) and field tests prior to their

registration and use in large scale within the country. Basic and applied research would be conducted to minimize losses from pests and reduce food-borne health risks. This project will assist in enacting pesticide and fertilizers laws and by-laws of the country.

Objectives:

- To develop/ improve laboratory and field based screening processes of agrochemicals.
- To assess the quality of agrochemicals used in agriculture.
- To identify pre-harvest interval (waiting period) for commonly used pesticides in the economical crops.
- To explore effective conventional agrochemicals and eco-friendly substitutes.

Expected Outcomes:

- Ensure the quality of used agrochemicals and eco-friendly substitutes.
- Recommend effective and safe agrochemical products and propose removal of ineffective and/or harmful pesticides from registration.
- Improve the marketability and profitability of the local agricultural produce.
- Reduce human health hazards related to consumption of contaminated agricultural products by pesticide residues.
- Ensure the contents of agrochemicals to be as per international standard.

Project 5.3. Optimization of Plant Nutrition Requirements

Rational:

According to the projections, food production on presently used land must be doubled in the next two decades to meet food demand of the growing world population. To achieve the required massive increase in food production, large enhancements in application of fertilizers and improvements of soil fertility are indispensable. Presently, in many developing countries, poor soil fertility, low levels of available mineral nutrients in soil, improper nutrient management, are major constraints of production. Plant nutrition research provides valuable information highly useful in the elimination of these constraints, and thus, sustaining food security and well-being of humans without harming the environment. The fact that at least 60% of cultivated soils have growth-limiting problems with mineral-nutrient deficiencies and toxicities, and about 50% of the world population suffers from micronutrient deficiencies make plant nutrition research a major promising area in meeting the global demand for sufficient food production with enhanced nutritional value in this millennium. Because of the environmental characteristics of Oman the soil is very poor in fertility. In addition there is a lack in plant nutrition studies. Although some studies were conducted to find out the optimum fertilizer requirement of some crops, it is still essential to develop a research plan to find out the optimum fertilizer requirement for the rest of the crops of the country.

Objectives:

- To solve problems of mineral-nutrient deficiencies and toxicities.
- Estimate the optimum fertilizer requirements for economic crops under shade, greenhouse and open field.
- Optimization of crop production to face population expanding.

Expected Outcomes:

- Defining the optimum fertilizer requirement of the economic crops of Oman.
- Saving soil & environment from the fertilizer pollution.

Project 5.4. Identification and Utilization of Plant Associated Soil Microorganisms**Rational:**

Beneficial soil microorganisms, such as *Rhizobium* and *Mycorrhizae* are of great importance for the soil and plant nutritional status. They help in providing plant nutrients, thus reducing the use of chemical fertilizers, which help in saving environment. Identification of the presence and quantity of these beneficial organisms in the Sultanate is essential in order to develop them. Also, the improvement of the efficiency of these organisms helps in improving their working quality. Propagation and production of the most efficient soil microorganisms including local *Rhizobium* and *Mycorrhiza* are necessary to suffice the need of the country as compared to available commercial microorganisms.

Objectives:

- Identification and quantification of local microorganisms.
- Propagation and improvement of the efficiency of soil microorganisms including *Rhizobium* and *Mycorrhizae*.

Expected Outcomes:

- Identification and mass multiplication of promising local beneficial microorganisms.
- Improvement of plant nutritional status and reduction in the use of chemical fertilizer.

Project 5.5. Development of Sustainable Pest Management Approaches**Rational:**

A number of pests and diseases have emerged as serious threats to the crops and caused severe losses to farmers. Witches Broom Disease of Lime, Mango Tree Decline and Alfalfa witches broom have resulted in significant reduction in the production and the cultivated areas. Integrated Pest Management approaches have been developed and successfully applied to control pests

and diseases under greenhouses (e.g. cucumber, tomato) and open field (e.g. mango, lime) in different regions of Oman. Developing efficient, sustainable and low-cost control techniques will contribute to reduce effect of pests and diseases and re-establish bio-ecological imbalances.

Objectives:

- To maintain major pests and diseases under economical threshold level.
- To develop effective and sustainable control measures for pest and disease management.

Expected Outcomes:

- Develop new pattern of applied technologies including sustainable and efficient methods to produce value-added fruit and vegetable products free of pests and pathogens.
- Harmonize agrochemical use and organic wastes accumulation related to pest and diseases control.
- Reduce time and energy requirements for production healthy and safe value added food product.
- Apply bioactive compounds such as bio-pesticides in association with improved physical, biological processes (solarisation, sanitation..) and enhanced cultural practices to achieve long-term threats control with minimal risk of harmful residues in produced food.

Project 5.6. Identification and Management of Honeybee Pests and Diseases

Rational:

Bee health is critical for the success of pollination-based agriculture and honey qualitative and quantitative production. A number of factors have contributed to the declining health of Omani honey bee colonies. These include several honey bee pests such as beetles, which can damage honey comb, stored honey and pollen, as well as deadly bee parasites such as the Varroa mite (*Varroa destructor*), tracheal mite and single-celled gut parasite. Honeybees also face a number of newly introduced diseases caused by viruses, bacteria and fungi. In addition, a new threat to honeybee health has been recently reported in the world, named colony collapse disorder (CCD). In colonies exhibiting CCD, adult bees leave the hive and never return, abandoning the queen and eggs.

Objectives:

- To determine the prevalence of parasites and disease-causing microorganisms that may be contributing to the decline of honeybee colonies nationwide in Oman.
- To better understand the factors threatening indigenous honeybees for effective action to prevent diseases and pests outbreak as well as to protect local honeybee colonies.

Expected Outcomes:

- Recommendations of alternative solutions for honeybee pest and diseases management.
- Non-use of chemicals which are harmful to bee and for the human consumption.

MP 6. BIOLOGICAL CONTROL RESEARCH AND DEVELOPMENT PROGRAM

Project 6.1. Survey and Identification of Indigenous Natural Enemies

Rational:

Development of effective biological control technology for major pests is necessary in terms of surveying, identification of the indigenous natural enemies and introduction of appropriate exotic natural enemies and microbial control agents of insects and fungal causal agents. Besides, it is also essential to develop and testing of technology for reliable identification of the locally adapted natural enemies of pests and diseases. Accordingly, effective, augmentative and classical biological control strategies for key pests could be developed.

Objectives:

- To identify and study local efficient and adapted biological agents in accordance with each agriculture plant protection problems.
- To develop locally efficient process for biological control pests and diseases.
- To provide novel techniques to manage pest populations below economic damage thresholds by the integration of biological and environmentally compatible strategies that are based on increased understanding of the biology and ecology of pests and diseases as well as their associated natural enemies.

Expected Outcomes:

- Development of cost-effective biological management practices without affecting environmental quality or posing a threat to human and animal health.
- Providing information and tools to apply biological control methods for various agricultural cropping systems.
- Recommending bio-control products without risks to human and animal health as well as the natural bio-eco system.

Project 6.2. Mass Multiplication and Utilization of Efficient Biological Control Agents

Rational:

The biological control approaches are the principal component of a sustainable integrated pest management for establishing priorities and recommending appropriate research and application of indigenous and exotic resources for pest and diseases management so as to be consistent with strategic Program Plan and decision policies. Mass multiplication of promising local and exotic bio-control agents have been initiated in Oman. More than 900 million of *Trichogramma* have

been reared locally and released for the control of pomegranate butterfly in Al-Jabal Al-Akhdhar. An interdisciplinary research integrates information and technologies for mass multiplication and utilization of the efficient biological control agents (in accordance with 6.1 project) to develop new practices and dynamic systems that optimally enhance safely productivity, profitability, energy efficiency, and conserve natural resource for different kinds and sizes of Omani farms.

Objectives:

- To conduct integrated research, development, demonstration, and technology transfer that provide information and biological safe tools to solve problems and address opportunities in farming systems, which conserve natural resource and enhance crop production, product yield and quality within safe environmental quality.
- To develop biological control strategies to reduce losses caused by pests and diseases those are effective with reasonable cost while maintaining environmental quality.

Expected Outcomes:

- Produce natural enemies in a large scale using low-cost diet / alternative hosts.
- Recommend the most efficient biological control application technique for an effective management of major pests.
- Enhance crop productivity and food quality within a safe environment.

MP 7. FOOD SAFETY AND QUALITY RESEARCH PROGRAM

Project 7.1. Physical and Chemical Characterization of Omani Date Palm Cultivars

Rational:

The number of the date's cultivars in the Sultanate is more than 250; nevertheless only the common cultivars were sporadically subjects of intensive studies whereas the rest had been neglected. A comprehensive physical and chemical characterization of those cultivars could reveal interesting results for processors, nutritionist and scientists. To obtain inclusive data, this project should be simultaneously carried out with the horticultural description of these cultivars.

Objectives:

- To obtain distinguish data about the physical - chemical properties of dates as well as horticultural description of Omani cultivars.
- To determine the differences between these cultivars in their properties.
- To classify the cultivars according to results.

Expected Outcomes:

- Establishment of data base for later applications.
- Highlight composition of the different Omani cultivars.

Project 7.2. Evaluation of Omani honey quality

Rational:

Beekeeping has been practiced since ancient times in Oman. Oman has a varied landscape represented in its dried-up river beds, hills, plains and deserts in which flourish the plants and trees which provide the honey bee with the nutrients it requires: palm trees, coconut palms, cereals, limes, vegetables, sugar cane, frankincense and gum trees. In particular the somr (*Acacia tortilis*), sidr (*Zizipus sp.*), and ghaaf (*Prosopis cineraria*) trees, coconut palm (*Cocos nucifera*) prickly pear (*Opuntia sp.*) and papaya (*Carica papaya*) trees provide the principal ingredients which give Omani honey its distinctive flavor. The aim of Honeybee Research Lab. of DGALR has been not only to control the quality of Omani honey but also to increase the quantity of production. The Ministry of Agriculture has imposed a strict ban on mixing Omani and imported strains of bees and provides veterinary services, advice, and material support to all Omani beekeepers.

Objectives:

- To prevent declining honey bee populations and honey production.

- To preserve local honey bees, required for both pollination of a multitude of crops and honey quality production.
- To improve the quality of local honey.

Expected Outcomes:

- Enhance production of healthy honey bee colonies/ broods and honey as a source of income for Omani farmers.
- Better understanding of food quality and natural pest control.

Project 7.3. Assessment of antibiotic residues in animal products

Rational:

By and large, the term 'antibiotic residue' is the small amount of an antibiotic or its breakdown product(s) that remains in meat, milk and eggs following treatment with the antibiotic. Antibiotics are widely used as therapeutic, prophylactic and growth promoting agents in livestock. These agents take different periods (time) for complete excretion from the body, which is called withdrawal period and it must be observed before consuming eggs, milk and meat. Neglecting withdrawal period leads to antibiotic residues in these food items. Antibiotic residues may produce pathologic effects including fatal allergic reactions autoimmunity, carcinogenicity, nephrotoxicity (gentamicin), bone marrow toxicity, mutagenicity, hepatotoxicity, and reproductive disorders. The most commonly used groups of antibiotics are beta-lactams (β -lactams) (e.g. penicillins and cephalosporins), tetracyclines (e.g. oxytetracycline, tetracycline and chlortetracycline), aminoglycosides (e.g. streptomycin and gentamicin), macrolides (e.g. erythromycin) and sulfonamides (e.g. sulfamethazine). Recent surveys revealed that antibiotics (penicillins) are the drugs most often prescribed or used in the treatment of lactating dairy cows. The five most prescribed β -lactams are: penicillin G, ceftiofur sodium, cloxacillin, cephalixin and ampicillin. A similar pattern of drug usage would be expected for other animals. Several countries have established tolerance/safe levels or maximum residue levels (MRL) of different antibiotics, below which, it is considered that the drug may be safely used without harming the consumer. No information is available concerning antibiotic residues in local animal meat, milk and eggs and products in the Sultanate.

Objective:

- To estimate the presence of commonly used antibiotic residues levels in animal products.

Expected Outcomes:

- Development of diagnostic facility for monitoring program.
- Propose safety and preventive measures for the control of drugs residues in food chain.

Project 7.4. Assessment of pesticide residues in agriculture products

Rational:

As results of rapid industrialization and modernization of the agriculture, the adverse effects of pesticides to human health and environment have become a serious concern in Oman. In order to sustain the development process, protect human health and environment and cope with the situations, a number of measures are being undertaken by the government. The Ministry of Agriculture contributes in managing agrochemical by setting up guidelines to achieve the safe use of pesticides in order to prevent food and environmental pollution. In order to activate the role of the ministry in monitoring the pesticides residues in the agricultural produce in the farms, the toxicology research lab has carried out several surveys around the country. It is therefore necessary to conduct intensive monitoring of the agricultural produce within the farms. In addition, the laboratory assists in the detection of pesticide residues in the imported agricultural products.

Objectives:

- To conduct extensive monitoring and inspection of farms for pesticide residues.
- To assist in monitoring imported agricultural products for pesticide residues.

Expected Outcomes:

- Establishment of stringent monitoring system of pesticides residues in crops.
- Secure safe and healthy food for local consumers.
- Minimize human health hazards related to the consumption of pesticide contaminated agricultural products.
- Improvement the marketability and profitability of the local agricultural produce.

MP 8. NON-CONVENTIONAL WATER USE PROGRAM FOR AGRICULTURE PRODUCTION

Project 8.1. Safe-Use of Treated Wastewater in Agriculture Production

Rational:

Sultanate of Oman suffers from water scarcity because of low rainfall and high temperature. Desalination is the key solution to meet fresh water demand for human consumption and industry despite high production cost. Treated wastewater could be available source of water augmentation. There are 350 treated wastewater plants in Oman. The expected production of treated wastewater (TWW) could be 100 million cubic meters per year in 2012 and this amount would increase to 220 million cubic meters per year from 2020 onwards. In view of this sense, several studies were conducted at Agricultural Research Station, Rumais, from 2004 to 2010 targeting the use of tertiary treated wastewater in the cultivation of forage and other field crops. From regional, Arabian and worldwide studies which explained the importance of treated wastewater, it can be seen that the treated wastewater is very important source of irrigation. The DGALR handled the three-year pilot project entitled "Utilization of treated wastewater in forage production" in collaboration with LNG Co. and the Ministry of Regional Municipality and Water Resources from December 2008 to December 2010 at Saham, the results of which successfully demonstrated that treated wastewater could be used productively for cultivation of annual fodder crops like barley, sorghum and maize throughout the year in reducing the pressure of scarce ground water resources. Recently, the Ministry has established "Treated Wastewater Research Farm" for extending research in other field and forage crops to increase their area of cultivation under treated wastewater for sustainable agriculture in Oman.

Objectives:

- To evaluate different cultivars / varieties of field, vegetables, forage crops and fruit trees for yield potential and quality with special emphasis on concentration of heavy metals.
- To evaluate effect of different methods of irrigation (drip, sprinklers, bubbler) using TWW on yield and quality of different agricultural crops.

Expected Outcomes:

- Increase of yield of forage and food crops using TWW as alternate source for irrigation.
- Saving the substantial use of fresh water.
- Reduction of water demand imbalance.

8.2. Utilization of Saline Water for Sustainable Agriculture

Rational:

Since large quantity of irrigation water available in the agricultural area is saline, it is essential to efficiently use it for crop production. Finding the most economical crop/species under the highest possible salinity level is a big goal, which can be achieved through screening with different management practices. Therefore different experiments will be conducted either under controlled or open field environment for selecting the most economically viable salt tolerant species in addition, to find out the best management practices suitable under the Sultanate environment. Several investigations have been undertaken since early 1990's to identify saline tolerant productive plant / crop species such as *Atriplex lentiformis*, *Atriplex canescence*, *Acacia ampliceps*, fodder beets, canola and high yielding varieties of annual forage crops such as sorghum and pearl millet to grow under varying saline environments. In addition, there were activities concerning both salinity affected soil and water for monitoring and appropriate management. The Ministry has established Biosaline Agriculture Research Farm in 2009 with required field and laboratory facilities for carrying out diversified activities of agriculture research using saline water.

Objectives:

- Surveying of water and soil quality for salinity status.
- Screening of crop varieties under different levels of saline water.
- Application of management practices for improvement of production under saline condition.

Expected Outcomes:

- Recommendations of suitable crop species/ varieties and management practices for economically viable bio-saline agriculture.
- Following up of the current quality of irrigation water at the Batinah coast farms.

MP 9. SURVEILLANCE OF LIVESTOCK EPIDEMICS AND TRANSMITTED DISEASES

Project 9.1. Surveillance and Monitoring of Emerging and Re-emerging Diseases

Rational:

Surveillance provides an early detection of diseases of concern in the region that enables the authorities to mount a swift control/eradication response which saves a great amount of national resources. Monitoring of animal diseases is a specific activity aimed at detecting changes in the epidemiological parameters of a specified disease. It follows as part of an early reaction should surveillance activities indicate introduction of disease and focuses more specifically on the identified disease in order to ascertain changes in prevalence level, rate and direction of spread. Livestock plays an important role in the rural economy of the Sultanate and Oman is also importing a large number of food animals to fulfill meat demands within the country. Similarly, game animals especially horses and fancy birds are also regularly imported over the year. Importing animals can be a potential source of introduction of infectious diseases in the region. Therefore, surveillance and monitoring of trans-boundary and zoonotic diseases is pivotal to prepare for proper protection of domestic animals and human population.

Veterinary Research Center (VRC) Oman receives approximately 6,500 samples annually from the veterinary clinics, private practices, and quarantine for diagnosis purposes. The data thus obtained are utilized for the passive surveillance of infectious/zoonotic disease. Currently, the Center focuses toward African horse sickness, Rift Valley fever, Lumpy skin disease, Glanders, West Nile disease, Equine infectious anemia, Q fever, and Viral arthritis. Since status/occurrence of avian influenza, rabies, blue tongue, Foot and Mouth Disease (FMD), *Peste des Petitis Ruminants* (PPR) and brucellosis is well known in the sultanate, monitoring is being carried out over the entire year. Both serologic and molecular diagnostic tools are employed for these purposes.

Objectives:

- To detect the prevalence of serious infectious diseases of animals and zoonotic importance.
- To determine the temporal and spatial trend of diseases.

Expected Outcomes:

- Contribute to control and eradication of trans-boundary and autochthonous diseases.
- Improve of diagnostic capabilities and early warning system.

Project 9.2. Patho-biological Studies of Animal Diseases

Rational:

Pathobiology of infectious and non infectious animal diseases, including biology of causative agent, pathogenesis, host susceptibility, mode of transmission, etc., is important to comprehend the pathogenesis of malady, to grasp emerging virulent strains and disease-initiating factor(s) present within the herd and to contain the spread of infections and plan/or conclude new preventive measures. Over the globe, livestock is susceptible to several pathogens / diseases which may cause humongous economic losses in terms of mortality and morbidity. These losses could satisfactorily be prevented when sufficient data on pathobiology of the disease is accessible. In Oman, livestock business is major source of livelihood of poor people living in remote area of dessert and mountains. The practice of introducing new livestock head to the existing herds invariably increases the risk of new infections/disease in the herds. Animals primarily take feed from rangelands and also fed, however rarely, by farmers. In such circumstances, nutritional deficiencies and metabolic problems also emerge. Therefore, a comprehensive understanding on patho-biology of existing and emerging problems is fundamental for necessary actions. The Veterinary Research Center, frequently carries out these studies especially in situation of out-breaks to feed back authorities and field veterinarians. Historically, the Department has comprehensively been studied path-biology of Newcastle Disease and concluded emergence of new (very virulent) strain in poultry. Given that the data on existing important animals diseases is scanty, patho-biological studies are warranted to determine the occurrence of the diseases and virulence and molecular typing of causative agents, antibiotic susceptibility of multi-drug resistant strains.

Objectives:

- To investigate the pathological alterations related to infectious and metabolic diseases.
- To determine bio-chemical, molecular typing and antibiogram of causative agents of different diseases.
- To understand role of virulence of the agents in the pathogenesis, and genetic homology of field strains in different regions.

Expected Outcomes:

- Better understanding about the pathogenesis of new and economically important diseases.
- Identify the sources of infections and mode of transmission.

MP 10. SUPPORTIVE SERVICES

Project 10.1. Production of Tissue Culture Date Palm Seedlings

Rational:

Agriculture Census - 2005* showed that there are three million date palm trees, which are non-productive. The strategy of date palm development includes a project for rehabilitation of non-productive date palm trees. In this respect, first batch of date palm tissue culture seedlings was produced by Jimah Tissue culture lab in 1996 which has increased its annual production capacity to the extent of 40,000 offshoots to date. MoA has distributed more than 1/4 million date palm offshoots among the farmers. Recently, the fund has been allocated to upgrade the annual production capacity up to 100,000 seedlings / offshoots.

Objectives:

- To strengthen the rehabilitation program under the Date palm improvement strategy.
- To minimize cost and time of propagation for commercial date palm varieties.

Expected Outcomes:

- Enrichment of the date palm trees for their commercial use and food security.

10.2. Production of Improved Fruit Trees Seedlings

Rational:

In Oman, many tropical, sub-tropical and temperate fruit trees are grown successfully for both domestic and commercial utilization. However, some of these fruit trees are non-grafted, limited in varieties and low yielding. The aim of the project is to disseminate the improved recommended cultivars free of pests and diseases to the farmers for the diversification of quantity and quality of fruit trees. The Ministry of Agriculture has established many fruit trees nurseries in Barka, Sohar, Al-Kamil, Jimah, Al-Jabal Al-Akhdar and Salalah for the production of thousands of fruit tree seedlings annually of recommended cultivars by DGALR. Every year Ministry celebrates Tree Day on 31 October and distributes about 80,000 fruit tree seedlings among the farmers.

Objectives:

- To rehabilitate the old horticulture orchards by the improved varieties.
- To assist the private sector nurseries in providing certified mother plants.
- To improve the fruit tree production in terms of quantity and quality.

*MoA. 2005. Agriculture Census - 2005. Directorate General of Planning and Investment Promotions. Department of Statistics and Information. Ministry of Agriculture, Oman.

Expected Outcome:

- Maintain biodiversity of fruit tree crops for food security.

Project 10.3. Diagnosis and Field Investigations of Plant and Animal Pests and Diseases

Rational:

The Veterinary Research Center (VRC) of DGALR is the integral part of the Department of Agriculture in respect to animal health, welfare and public health. The Center provides efficient diagnostic services to control livestock and poultry diseases of economic and zoonotic importance. The Center receives every year approximately 6,000 samples comprising of morbid tissues, carcasses, blood, serum, feed, etc annually to investigate the problems. These samples are received from veterinary hospitals, quarantine facilities, municipality departments, and livestock keepers. Diagnosis is done using pathological lesions, isolation and identification of pathogens, serology and molecular analysis of the samples. The results records are kept on excel on sheet on daily basis and subjected to statistical analysis, finally published in monthly reports to observe the trends of diseases and respond accordingly. Field investigations are preferred mostly on important infectious and contagious disease threats rather than metabolic problems to improve the health of livestock and protect especially the Omani indigenous stock of animals. Important epidemiological studies undertaken during the last five years include on screw worm, equine piroplasmiasis, rabbit hemorrhagic disease, Newcastle disease, and bovine and caprine mastitis.

The Plant Protection Research Center of DGALR provides efficient services of consultancy to the problems of farmers in terms of diagnosis of diseases and pests based on plant samples and recommending appropriate control measures. The Center receives approximately 1000 samples every year comprising of soil, leaf, shoot and roots of fruit trees, field and vegetable crops and fodder and forage species to investigate the problems. These samples are received from individual farmers, companies and institutions/ organizations. Diagnosis is done using pathological lesions, isolation and identification of pathogens like bacteria, fungi, nematodes, viruses, phytoplasma and insect pests. Field visits and investigations are performed for those fields infested heavily by particular plant diseases and pests. Important epidemiological studies of most important plant diseases and pests undertaken during the last ten years include on Witches broom disease in lemons and alfalfa, mango midge, pomegranate butterfly, Dubas bug, Red palm weevil and Lesser date moth in Date palm, coconut mite.

Objectives:

- To diagnose commonly existing and emerging animal disease and pests problems.
- To monitor and diagnose different pathogenic and physiological diseases, and insect pests of several agriculture materials, seedlings and seeds.

- Field visits/ investigations of economically important and zoonotic diseases in animals, and pests and diseases in plants.

Expected Outcomes:

- Prevention of epidemic animal and plant pests and diseases.
- Control of animal and plant pests and diseases.
- Improve health of livestock and prediction of occurrence and pattern of new diseases in animals.

Project 10.4. Laboratory Analysis of Soil, Water, Plants and Fertilizers

Rational:

In Oman, the facilities of analysis of soil, water, plants and fertilizers have been available since the inception of agriculture research. Due to shortage of laboratory analysis facilities in the private sector, the MoA has taken initiative to provide these facilities to the individual farmers, companies and institutions. Every year, thousands of samples of soil, water, plants and fertilizers, are received for analysis.

Objectives:

- To analyze physical and chemical properties of soil.
- To analyze chemical contents of plants, water and fertilizers.

Expected Outcomes:

- Minimize the economical loss of the farmers and side effects of chemicals for the environment and human health.
- Ensure the contents of fertilizers as per international standard.

Project 10.5. Capacity Building (Students' Training, On-Job Training, Field Visits, Field Days, Workshops and Conferences)

Rational:

Capacity Building is much more than training and includes i). Human resource development, the process of equipping staff of the Ministry with the understanding skills and access to information, knowledge and training that enables them to perform effectively, ii). Organizational development of the Ministry, the elaboration of management structures, processes and procedures, not only within Ministry but also the management of relationships between different institutions/ organizations and among the Directorates and Departments of Agriculture & Animal Wealth of the Ministry.

The Ministry of Agriculture is often provided with capacity building by national (SQU, TRC, MRMWR, Diwan of Royal Court, etc.) regional (GCC organizations/ institutes) and international organizations like FAO, ICARDA, ICBA, AOAD etc. as a part of their programs of technical cooperation with their member countries. Bilaterally funded organizations/ institutes and private sector consulting firms would also offer capacity-building services.

In the context of the DGALR, capacity building is concerned with student's training, on-job training, conducting field days and field visits and holding workshops and conferences, based on necessity and need of the Ministry.

Objectives:

- To depute the staff for higher training in any specialized areas of agriculture for improving qualifications.
- To conduct annually training for students of the academic government and private institutions.
- To conduct field days to demonstrate farmers about the recent outcomes of agriculture research.
- To conduct field visits by the team/s of researchers to attend the farmers' field problems.
- To conduct workshops and conferences on the important issues of agriculture and livestock, in association with international / regional/ local organizations involving all the concerned staff of the Ministry and other stakeholders of the country.

Expected Outcomes:

- Enhancement of human resource development of Ministry's staff in terms of quantity and quality.

11. COOPERATION WITH REGIONAL AND INTERNATIONAL ORGANIZATIONS

Agriculture and livestock research activities in the Ministry of Agriculture are going on with strong cooperation with the following International and regional organizations in terms of consultancy, human capacity development including training, education etc, exchange of research material etc.

- AARINENA - Association of Agricultural Research Institutions in the Near East and North Africa, AARINENA Secretariat, c/o ICARDA West Asia Regional Program (WARP), PO Box 950764, Amman 11195, Jordan.
- ACSAD - Arab Center for the studies of Arid Zones and Dry Land, Syria.
- AOAD - Arab Organization of Agriculture Development, Arab Organization for Agricultural Development Amarat street 7 P. O. Box 474 Khartoum 11111 – Sudan.
- BI - Bioversity International (earlier IPGRI- International Plant Genetic Resources Institute), Bioversity Headquarters, Via dei Tre Denari 472/a 00057 Maccarese (Fiumicino), Rome, Italy.
- CGIAR - Consultative Group on International Agriculture Research, c/o Food and Agriculture Organization of the United Nations (FAO), Viale delle Terme di Caracalla, 00153 Rome, Italy.
- CIAT- Centro International de Agricultural Tropical, Km 17, Recta Cali-Palmira Apartado Aéreo 6713, Cali, Colombia.
- CIMMYT - International Center for the Improvement of Maize and Wheat, Km. 45, Carretera Mexico-Veracruz, El Batan, Texcoco, Edo. de México, CP 56130 Mexico City, Mexico.
- FAO - Food and Agriculture Organizations for the United Nations, Regional Office, Cairo., HQ- Rome, Italy.
- GCC - Gulf Cooperative Council of six GCC states viz. Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates. Head Quarters- Jeddah, Saudi Arabia.
- GCDT - Gobar Crop Diversity Trust, A Foundation for Food Security, c/o FAO Viale delle Terme di , 00153, Rome, Italy.
- ICARDA - International Center for Agriculture Research in the Dry Areas, PO Box 5466, Aleppo, Syria.
- ICARDA-APRP - ICARDA's Arabian Peninsula Regional Program, PO Box 13979, Dubai, United Arab Emirates (UAE).
- ICBA - International Center for Biosaline Agriculture, PO Box 14660, Dubai, United Arab Emirates.
- ICRISAT - International Crop Research Institute for Semi Arid Tropics, Hyderabad, India.
- IITA - International Institute of Tropical Agriculture, Headquarters IITA-Nigeria Ibadan, PMB 5320, Ibadan, Oyo State, Nigeria.

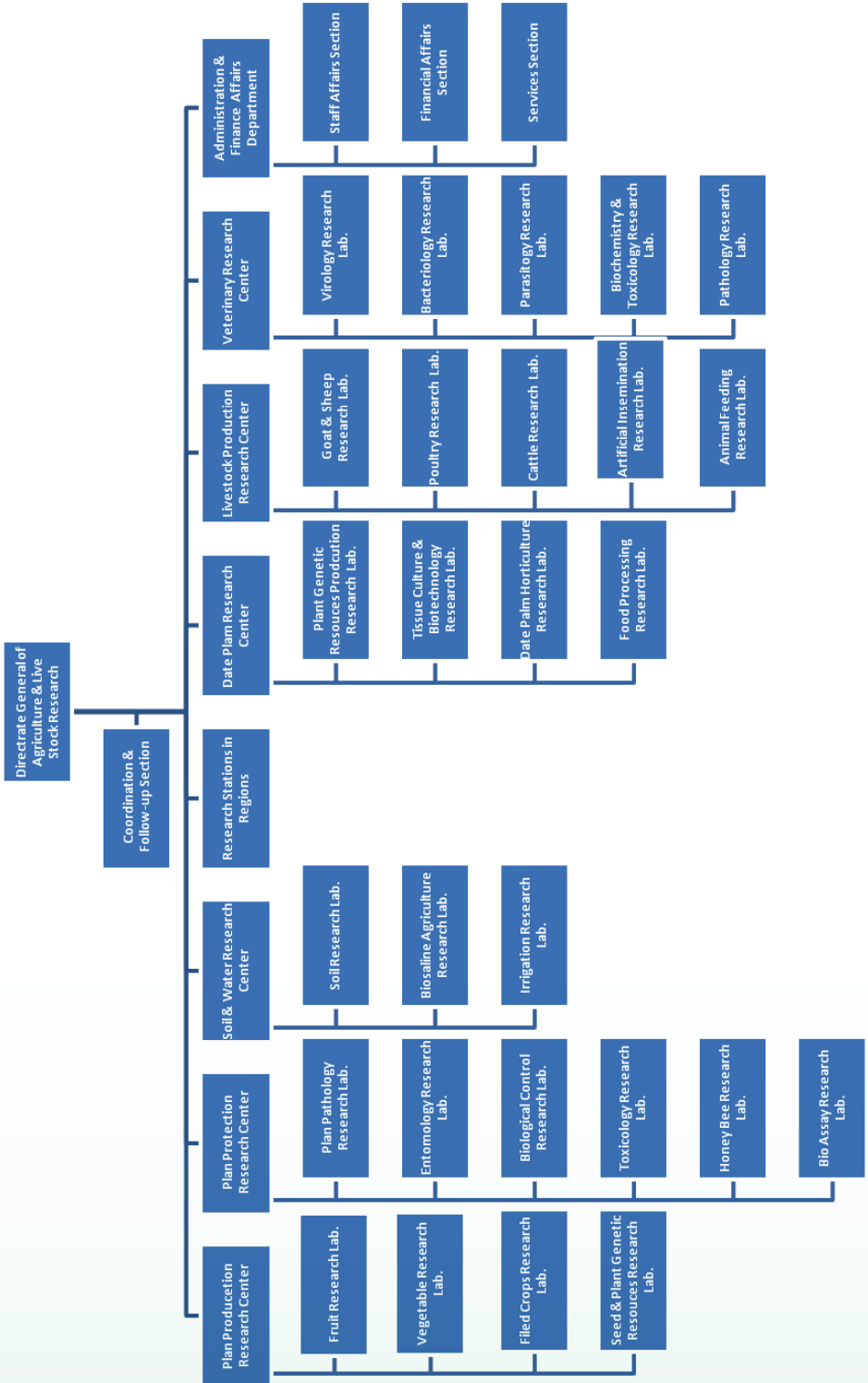
- ILRI - International Livestock Research Institute, P.O. Box 30709, Nairobi 00100, Kenya. P.O. Box 5689, Addis Ababa, Ethiopia.
- ISHS - International Society of Horticulture Sciences, ISHS Secretariat, PO Box 500, Leuven, BelgiumIAEA - International Atomic Energy Agency, International Atomic Energy Agency, Vienna International Centre, PO Box 100, A-1400 Vienna, Austria.
- JICA - Japan International Cooperation Agency, Nibancho Center Building 5-25, Niban-cho, Chiyoda-ku, Tokyo 102-8012.
- OIE - Office International Epizootic, World Organization for Animal Health, 12, rue de Prony, 75017 Paris, France.
- UPOV - The International Union for the Protection of New Varieties of Plants, 34, chemin des Colombettes CH-1211 Genève 20 Switzerland.
- USDA - U.S. Department of Agriculture, 1400 Independence Ave., S.W. Washington, DC 20250.
- WHO - World Health Organization, Avenue Appia 201211, Geneva 27, Switzerland.

ABBREVIATIONS

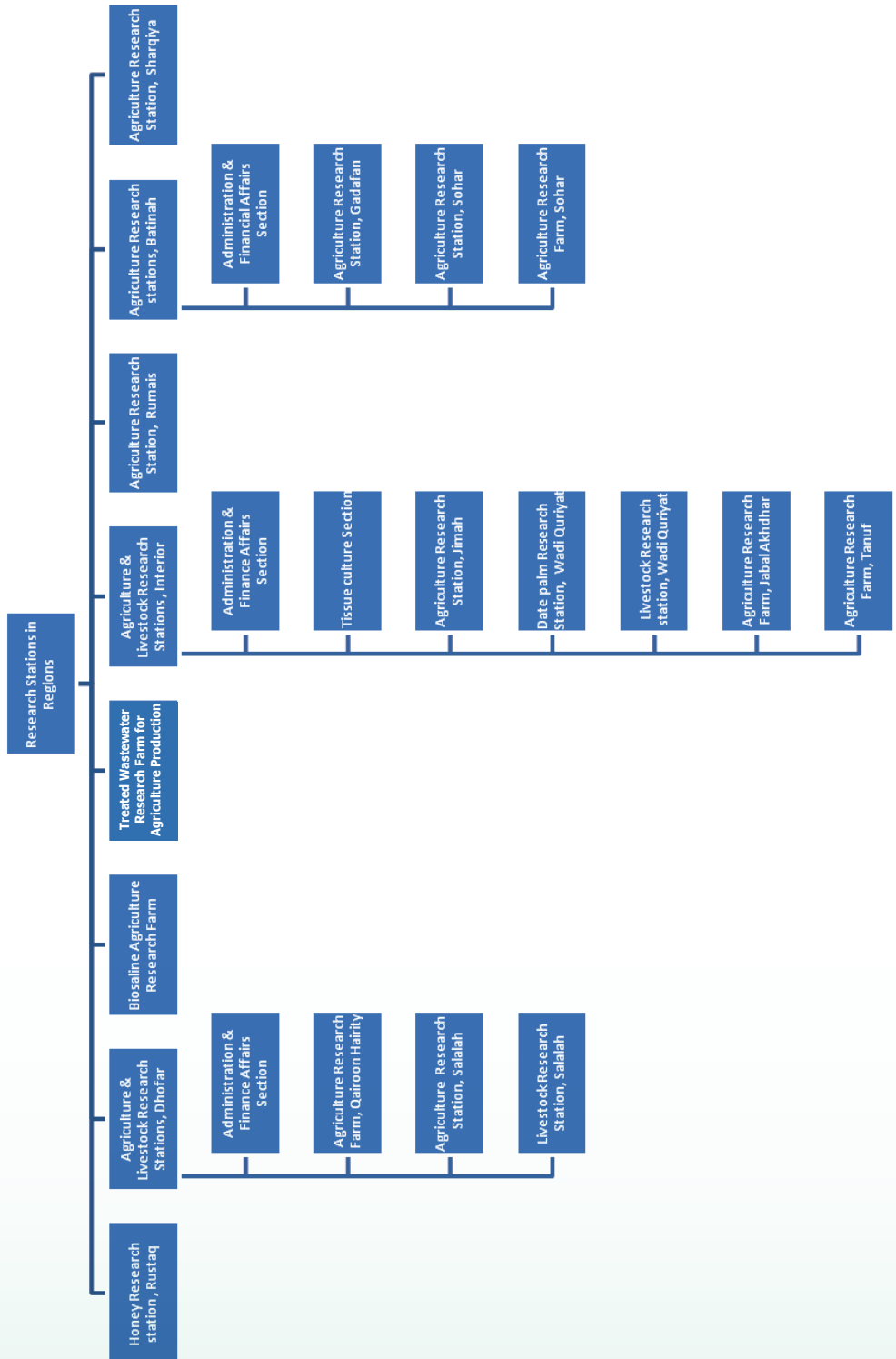
- CCD - Colony Collapse Disorder
- CWR - Crop Wild Relatives
- DGALR - Directorate General of Agriculture & Livestock Research
- GDP - Gross Domestic Product
- IPM - Integrated Pest Management
- LNG - Liquefied Natural Gas
- MoA - Ministry of Agriculture, Sultanate of Oman
- MP - Mega Program
- MRL - Maximum Residue Level
- MRMWR - Ministry of Regional Municipality & Water Resources
- PGR - Plant Genetic Resources
- PGRFA - Plant Genetic Resources for Food & Agriculture
- SQU - Sultan Qaboos University
- TRC - The Research Council
- TWW - Treated Waste Water
- VRC - Veterinary Research Center
- WUE - Water –Use Efficiency

APPENDIXES

APPENDIX I



APPENDIX II



APPENDIX III**List of the staff of Directorate General of Agriculture & Livestock Research along with qualifications till December 2010**

Sl. No.	Qualification	Number of Personnel
1	Expatriate Experts	5
2	Omani Researchers with Ph.D.	12
3	Omani Researchers studying Ph.D.	17
4	Omani Researchers with M.Sc.	19
5	Omani Researchers studying M.Sc.	6
6	Omani Researchers with B.Sc.	70
7	Omani Researchers studying B.Sc.	5
8	Omani Technicians with Diploma	13
Total		147



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