MODERN AGRICULTURAL PRACTICES IN THE ARID REGIONS (KUWAIT)

H. A. Al-Zalzaleh
Desert Agriculture and Ecosystems Program, Environment and Life Sciences Research Center, Kuwait Institute for Scientific Research, 13109 Kuwait

Abstract
This paper discusses various factors that affect the expansion of greenery and agriculture in Kuwait. The State of Kuwait encourages large-scale agricultural production using modern agricultural practices and new knowledge to promote local food production. Different regions required to develop appropriate techniques for agriculture to fulfill food demand due to population increase in that area. Arid regions in the world have large land areas and are the most vulnerable to environmental changes, long-term drought, and degraded soils. To overcome such problems, appropriate methods and techniques have to be practiced. This paper focuses on the methods and techniques utilized in Kuwait for sustainable agriculture and increase food production. So far, the followings have been practiced to achieve the goals: water treatment, tissue culture, production of organic fertilizer, and research and development on existing resources. This paper also includes recommendations to improve agricultural production in an arid region.

Key words: treated water, green houses, tissue culture, organic fertilizer

1. INTRODUCTION
Gulf countries are under increased pressure to act against the population growth, increased prices of food supplies and the vagaries of climate changes. In addition, the application of new agricultural methods and imparting of effective irrigation systems on wide range of crops make the situation more critical. Climate changes, exploitation of natural resources, and loss of agricultural fertility lead to low productivity and quality of food, which in turn result in high cost of cultivation. So, government initiatives should be directed towards finding suitable solutions that are adaptable with minimum efforts without altering the environment. According to the conclusions of Food and Agriculture Organization (FAO) conference in Rome (2014), objective 2 was set, which focused on food security and sustainable agriculture (Proceedings, 2015). Sustainable agriculture is to use energy, water, economy, technology and natural resources in harmony to guarantee constant and continuous productivity to keep the environment safe and to consider agricultural regulation. In addition, objective 2 also aims at providing 500 million farms all over the world.

Gulf Co-operation Council (GCC) countries are paying enormous interest in the development of their own agricultural resources. The declaration of the common agricultural policy by the officials of GCC countries held during November, 1985 calls for developing the agricultural sector through four well-defined programs. Among these, the most important was the program of the agricultural researches and technological development that aims at finding scientific and practical solutions for the challenges that using and managing natural agricultural resources within GCC countries (Al-Khateeb 1988). According to the indicators of International Food Security, considering its ability to provide food security during the year 2014, Kuwait ranked first on the Arabian level and 28th internationally, amongst 129 countries (Al-Dhafiri 2016).

The Arabian Peninsula and Gulf region are classified as dry and arid lands. The State of Kuwait, situated in arid desert coastal environment, comprises only 17818 km², and was affected by negative environmental impacts and harsh activities from long ago. Due to its small geographical size, the disparity in climate between the areas is quite minimum. The prevalent climate, especially the temperature and rainfall, is considered as one of the most important factors that controls the environment. According to Omar (1985), Kuwait has a dry desert climate and the temperature varies drastically during seasons. The land of Kuwait is a flat plain sandy terrain intervened with small hills and is distinguished with harsh environmental and climatic conditions, known for the repetition of arid
In addition, there is dominance of dry wind and acute variations in rainfall pattern at an annual rate of 114-117 mm is prevalent. The intensity of rainfall is more during November until April, and spreads within winter and spring. Other major environmental challenges are high temperature levels that recorded as more than 50°C in shaded condition and the occurrence of sandy storms and prolonged daytime. No doubt that this kind of unfavorable climate has its own negative impacts on agriculture, and it doubles when it is combined with frost. Table 1 shows the average temperature of soil surface in summer for selected areas in the world. In Kuwait, winter temperature is 18°C during noon hours and sometimes reaches to 0°C, or below zero, which leads to the occurrence of frost in some desert areas of Kuwait.

<table>
<thead>
<tr>
<th>Location</th>
<th>Maximum Temp. (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kuwait</td>
<td>85</td>
</tr>
<tr>
<td>Heights of Red sea</td>
<td>82.5</td>
</tr>
<tr>
<td>Sahara</td>
<td>72</td>
</tr>
<tr>
<td>Arizona</td>
<td>71.5</td>
</tr>
<tr>
<td>Agra Desert (India)</td>
<td>69</td>
</tr>
</tbody>
</table>

**Table 1.** Average temperature in summer for selected areas in the world.  

For the formation of developmental agricultural projects, field studies should be conducted in order to generate reliable data on the nature of the climate, the land, and cultivated crops under prevalent environmental conditions. Plant production and growth of plants are related to the physical and chemical properties of the soil, and climate is important while considering the crop production in a sustainable manner. Land areas suitable for agriculture in Kuwait are estimated to be about 1.540 million donum, which constitutes only 8.63% of the total land area. Water is considered as the most precious resources in Kuwait, because natural water resources are limited and non-renewed due to the lack of rainfall. In addition, the compensation through recharging of underground water is limited. This emphasizes on finding alternative water resources, even though Kuwait depends highly on desalination of seawater for its day-to-day activities. Table 2 shows the categories of available water based on the concentration of total of dissolved salts present in it. The per head consumption of water in Kuwait is increasing day by day, resulting in the large production of sewage water. In order to overcome the shortage of water resources, it is important to treat sewage water for the use in agriculture and allied activities. Table 3 presents the amounts of soil acidity and water salinity in the irrigation water used for agricultural purposes in Kuwait.

<table>
<thead>
<tr>
<th>Water type</th>
<th>Total of salt dissolved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh</td>
<td>0-1000</td>
</tr>
<tr>
<td>Brackish</td>
<td>1000-10,000</td>
</tr>
<tr>
<td>Saline</td>
<td>10,000-100,000</td>
</tr>
<tr>
<td>High salinity</td>
<td>More than 100,000</td>
</tr>
</tbody>
</table>

**Table 2.** Categories of irrigation water based on total dissolved salts.  
Contamination of soils with dissolved salts leads to various health and environmental problems. If the farmers do not follow adequate scientific practices to replenish the accumulated salts in the upper horizons of the soil (Al-Khateeb 1998). The increase of salinity in soil affects the physico-chemical and biological characteristics of the soil, which in turn affects the physiology, growth, and crop yield. The frequency of deterioration of soil depends on the type and concentration of salt within the soil (Khalil 1988). The soil of Kuwait is generally sandy in nature with low organic matter and high in sodium chloride. A high percentage of exchangeable sodium (>15%) in the soil leads to accumulation of salts in the soil and low water percolation (Al-Khateeb 1998). High temperature in summer periods increases the rate of evaporation, resulting in the formation of marshes with salty crust and marshes in low lands from which the underground water level reaches the surface (Misak 1998). The soil salinity varies from one area to the other, and the presence of hardpan (calcareous soil) at a depth of 70-1.70 m is identified by Al-zalzaleh (1995). The harsh environmental conditions prevalent in Kuwait limits plant growth and vegetative development, results in low organic matter content (1%) in the soils (Al-zalzaleh 2016). The limited organic matter affects the fertility and microbial activities in the soil and the crop productivity. The low fertility of the soil is attributed to the harsh climatic conditions of the region.

Food production subject is considered to be an obsession within the field of environmental and economic changes; also, the percentage of population growth increases significantly, which means the increase of food requirements and demands. Thus, the only solution is to rely on internal production and to limit the demand on external imports, beside depending on sustainable agriculture. Sustainable agriculture is a complete integrated system that contains a relationship between the plant, animal, climate, human beings, scientific and economic applications. Arid lands confront too many difficulties and obstacles that prevent agricultural activity from developing through sustainable agriculture and the possibility of providing long-term solution for agricultural problems (Shiva & Bedi 2002).

With the development of civilization that included Kuwait within different fields, agriculture took care of this need and it is worth mentioning that Kuwait cannot be expected to be a food production country, despite which, there should be a continuous food industry capable of providing basic food needs and demands of high standard. Kuwait has seriously considered the agricultural activities and finding solutions for them by adapting new techniques and technologies in agricultural fields as an alternative of conventional agriculture. Technology is important for the agricultural development of GCC countries to help in facilitating agricultural activities and providing work force. Kuwait has played a major part in the process of increasing agricultural production as a result of allocating agricultural lands for more the 5000 farms of plants, animal, and fisheries projects. The strategic plans for marine culture to enrich the fish stock in regional water and to enforce food security. Kuwait Institute for Scientific Research (KISR) has released about 165,000 fish larvae of different species in regional water to rehabilitate fish stocks, and to support local fisheries, hatcheries and floating farms based on new technologies. Researchers of KISR for the first time succeeded in growing Greasy grouper (Hamour), Silver sea-bream (Subaiti), and Strommatus (Zubaidi).

This paper focus on some of the procedures and methods followed in Kuwait to decrease the food gap through finding solutions for sustainable agriculture, to ensure food security and achieve agricultural development through sustainable crop production.
2. SOLUTIONS FOR SUSTAINABLE AGRICULTURE

2.1. Treated waste water

The availability of water for irrigation is one of the major challenges to agricultural activity in the State of Kuwait. Prior consideration to nonconventional water resources is critical for sustainability. Among the different resources, treated municipal wastewater is the first option to be used to as a substitute for saline underground water and costly fresh water for daily irrigation needs to increase the productivity. Mineral concentration in this treated irrigation water is around 1000-1500 mg/liter (Abduljawad & Akbar 2015). For limiting the demand for fresh water, the wastewater undergoes either tertiary treatment or reverse osmosis filtration under strict scientific guidelines. By achieving this, a total of over 300 million gallons/day of treated waste effluent can be used (equals 1.36 million m³/day). Utilization of treated wastewater provides a secure, sustainable, and increasing source of water to maintain greenery and agriculture in the country, which is essential since ground water is non-renewable and could grow scarce crops within a certain period (Abduljawad & Akbar 2015). Currently, tertiary treated water is used for planting seedlings and ornamental plants, while the water treated through reverse osmosis is used for irrigation of fodder and vegetables, as well as cooling greenhouses in the summer. All of this makes treated water as the most important and strategic resource for agricultural production. Table 4 shows types and quantities of water used in agriculture in Kuwait.

<table>
<thead>
<tr>
<th>Type of water</th>
<th>Quantity (Million/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desalination sea water</td>
<td>36</td>
</tr>
<tr>
<td>Ground water</td>
<td>357</td>
</tr>
<tr>
<td>Treated water</td>
<td>90</td>
</tr>
</tbody>
</table>

Table 4. Quantity of water used in agriculture in Kuwait.


2.2. Protective agriculture

One of the current activities of the Agricultural Production in Arid Zone Program is protective agriculture. Protective agriculture is the production of crops within nurseries or greenhouses where climate conditions are controlled. The Desert Agriculture and Environmental Program (DAEP) of Kuwait Institute of Scientific Research aims at developing greenhouses to guarantee advanced cooling systems, improved environmental conditions for production, and improved methods of preserving water such as using hydroponic system. When the soil temperature reaches above 60°C, the functioning of living organisms are affected. Therefore, it is essential to use greenhouse for agriculture (Al-Fil & Al-Mutawa 1983). The usage of greenhouses were proved to be as the most successful methods of plant production in harsh environments that secures year round production and repeated production of crops without the constraints of agricultural seasons, in addition, to achieving an increase in yield volume and variety. For example, an area of 1m² in greenhouse will yield many times the production of the same area in an open field. The use of greenhouses and plant growth chamber with the appropriate controlled environment agriculture (CEA) techniques helps to create suitable conditions for agricultural production in arid zones through the control of climatic conditions that otherwise pose great challenge. According to statistics provided by the Public Authority for Agriculture Affairs and Fish Resources (PAAFR) for the year 2011, the number of cooled greenhouses had reached a total number of 29,630 in Kuwait.

2.2.1. Hydroponic agriculture

By adopting soilless cultivation, a practical solution to scarcity of high quality irrigation water and elimination of fertile soil that can sustain agriculture can be achieved in dry regions. Hydroponic systems are practicing in greenhouses to minimize the usage of irrigation. This advanced method improves water efficiency by lowering the water consumption at the lowest rate possible. The results of many scientific
studies indicated that it was possible to lower water consumption by as much as 90% when compared to conventional agricultural practices. This involves arranging plants in channels in tubs containing the required nutrient solution while minimizing the water used for irrigation and by recycling the nutrient solution in a closed hydroponic system. This system also reduces the labor required by enabling production of crops on daily basis, out of season, and with high quality. These techniques are also unaffected by poor soil and do not cause any pollution to the environment. Therefore, their usage has a positive impact on the environment and on sustainable development of agricultural activity, as they are of high technical and economically feasible. In view of the sustainable economic yield all year round, majority of farms in now Kuwait decided to switch from conventional practices to hydroponic systems for growing vegetables and fruits.

2.2.2. Controlled Environment Agriculture (CEA)

This method is commonly used to hike the agricultural productivity in the country using up-to-date scientific methods and tools to overcome challenges. Kuwait region is exposed to heavy sunlight, that requires advanced system options including CEA. Here, like in conventional agricultural methods potting soil or vast land space is not required, and the environment is controlled (quality and quantity of artificial light, temperature, and humidity) to facilitate the optimum climate for crop production. The practice of vertical farming makes it possible to plant more crops in a more sustainable manner when compared to conventional farming. The use of Light Emitting Diode (LED) systems provides the optimum light composition (white-red-blue), and research findings indicate that plants (strawberry) in (CEA) chambers grow and mature faster than plants in conventional farming greenhouse.

2.3. Tissue Culture.

Biotechnology in agriculture is one of the main fields where science contributes directly to the development of plants and increased agricultural production. The tissue culture laboratory at KISR was inaugurated in 1995 and is one of the most advanced laboratories of its kind and can produce some 50,000 palm trees/yr. The aim of establishing the laboratory was to increase production as part of the ongoing research activities in an effort to overcome the environmental challenges by utilizing country’s natural resources to achieve food security. The advantages of palm trees produced through tissue culture techniques are fast propagation of desirable plant species, minimum production cost, elimination of pests and diseases, and minimum failure of saplings.

Hybrid palm species produced in Kuwait, yielding dates with no pits, is considered to be the first of its kind in the world. Kuwait has succeeded in developing techniques to produce 26 premium species suitable for Kuwait’s environmental conditions. These varieties had originally been brought from Morocco, Egypt, Iraq, Saudi Arabia, Oman, Iran, and the United States. According to 2011 statistics of PAAFR, a total number of 1,570,000 palm trees were planted till then. These trees help achieve food security in many Arab countries, and the dates fruit produced can last and be stored for a long period. Researchers at KISR also succeeded in the tissue culture production of premium virus-free species of potatoes, and the saplings are now distributed to farmers in Kuwait and the GCC countries. Kuwait also succeeded in the tissue culture production of some indigenous plants for use in desert rehabilitation projects. This is considered the fastest and most efficient method to restore the ecosystem.

2.4. Fertilizer Manufacturing

Kuwait’s soils contains an organic matter of less than 1% of its weight and is categorized as unfertile soil. Adding organic matter to sandy soil rectifies many problems and increases soil fertility and efficiency. Organic matter plays an important role in vitalizing microorganisms in soil, and it is a means of hiking production. It also helps keep soil temperature down since it retains water and improves soil alkalinity and texture by introducing an agent that helps grains of sand bond together, thus increasing soil’s ability to hold water. Table 5 shows the types of organic fertilizers based on their origin and percentage of nitrogen based on dry volume.
### Table 5. Percentage of nitrogen in dry volume present in organic manures.

<table>
<thead>
<tr>
<th>Animal Source</th>
<th>Nitrogen (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cows</td>
<td>1.9</td>
</tr>
<tr>
<td>Goat</td>
<td>1.87</td>
</tr>
<tr>
<td>Poultry</td>
<td>3.77</td>
</tr>
</tbody>
</table>

Source: Compiled from the results from the laboratory of Environmental Research and Life Sciences, KISR (2016).

As a result of determining soil properties, more attention was given to focus on organic fertilizers and improving these with modern techniques. To solve the problem of poor soil organic content, companies were established to manufacture all types of fertilizers from waste matter after sorting and treating them in a manner that preserves the environment while sustaining high quality of product. Compost is fertilizer made by mixing organic matter, to keep up fertility replenishment in the soil. In addition, sterile fertilizer production plants were established to use waste matter from animal farms to produce fertilizers at high volume, high quality, and at economical cost. Treated organic fertilizers are odorless, have high organic content, and contain no fungi or weed seeds.

#### 2.5. Research and Development (R&D)

To realize strategic food security for a comprehensive nutritional development, and to increase agricultural production in Kuwait, studies and scientific research must be taken into priority. The State of Kuwait realized the importance of scientific research as a main pillar for developing the agricultural sector and continuing scientific support for finding solutions for different problems faced. It also realized the importance of sharing results and outcome of research for promoting modern, locally fine-tuned techniques to serve end-users (farmers). The State of Kuwait has assigned KISR for conducting various scientific research and technological development activities in the country. The KISR is very keen to find practical solutions for natural resources, better utilization of studding means of utilizing water and energy sources, and importing the methods used in agriculture. Among the latest research projects at KISR are the production of bio-fertilizers for use in different agricultural systems, and inoculation of mycorrizal fungi from local soil and injecting it into roots of local crops, which is a promising method of producing sustainable crops. Some studies on high-salinity soil in desert environments revealed that the soil turned fertile and productive within a short period of injection of microorganisms (Al-Zalzaleh 2016). Plants (tomatoes) treated with bioorganic fertilizers showed good vegetative growth and grew higher and yielded bigger fruit with less disease. Using bio-fertilizers reduces consumption of chemical fertilizers and deposition of nitrogen into the soil, therefore reduces the impact on the environment.

KISR is also intends to produce organic matter to serve in place of planting soil in organic farming. Aiming to increase vegetation and preserve the environment, new tree species capable of withstanding local climate and environment conditions were introduced after subjecting them to the required testing and screening. These species include *Ziziphus jujube*, *Olea europea*, *Argania spinosa*, *Acasia sayel*, and *Glicidcia sepium*, which have become familiar trees in Kuwait as well.

For example, an evaluation trial had been carried out to study the adaptability of *G. sepium* under the arid climatic conditions of Kuwait and to determine the suitability of interplanting of *G. sepium* with *Conocarpus*. Field study with 22 provenances were carried out in a randomized block design and the results showed significant differences (p<0.01) between the provenances, with Retalhuleu having recorded significantly higher growth characteristics. The plant growth under low density planting of 3 m × 1 m recorded the higher values for plant height, canopy area, collar diameter, and leaf area for *G. sepium* and *Conocarpus sp*, respectively (Al-zalzaleh et al. 2015).
3. CONCLUSIONS

- More and more experimental studies and its field applications in the areas of water, salinity stress, organic fertilizers and green houses are required to attain food security.

- Collaborative studies and research communications with other research institutions in the same fields of study is required to find suitable methods and solutions for current and foreseen challenges.

- Assuring adaptable standards and modern techniques on concerned subjects that suits the local conditions to the needy and facilitation to access the information.

- Participation in regular conferences and seminars on the concurrent subject of importance and their outcomes should be transferred to end users to attain sustainable crop production and food security.

- Implementation and upholding of legislation and regulations for farming to facilitate the economic integration and cooperation among the states of the GCC.

REFERENCES


