GREENHOUSE MANAGEMENT AND BEST PRACTICE IN EGYPT

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ABSTRACT

Management of greenhouses and protected cultivation requires proper knowledge of the climate and suitable environmental conditions for the cultivated crops. To achieve good management practices for greenhouses, the impacts of climate variables on plant growth and production during different seasons should understood. Autumn is the major cultivation season for greenhouse activities in Egypt, especially for vegetable crops production. Crops which are cultivated during autumn continue until winter or spring. Protected cultivation sector plays a significant role in terms of food security in Egypt and provides wholesale markets with fresh vegetable leafy and fruits during the winter season with a proper quantity and reasonable price. Using soilless culture techniques for commercial production of vegetable crops under greenhouses has started to expand in the last ten years, especially producing leafy crops during summer season. Producing tropical fruits under screenhouse has also started to expand commercially during the last five years due to increase in the extreme weather events (heat waves) during critical phenological stage especially for mango trees. The protection of mango trees by using white screen net cover and cheap wooden greenhouse structure has become one of the good management practices for producing high yield and good quality products. Greenhouse irrigation water management for vegetable crops is considered one of the most important practices related to proper production. An example involving the estimation of the irrigation water schedule during the autumn season in the Delta region is illustrated in this paper. The irrigation schedule was done based on the climate conditions of the Delta region which is demonstrated in the current work. The objective of the this paper is demonstrate the current status of the greenhouse management and practices in Egypt as well as review some efforts which developed during the last two decades such as local soilless culture technique and cultivate the tropical fruits under greenhouses which needed for the different stakeholders in the greenhouse sector in Egypt. On the other hand, the current work emphasis on the dominated climate in Nile Delta region and how to estimate the irrigation requirements for plants under greenhouse according to climatic data with review the researchers' efforts in this topic.

Keywords: Protected cultivation – screen net – tropical fruits – soilless culture – climate modification.

1 INTRODUCTION

Greenhouse production of fresh leafy vegetables and fruits is an important agricultural practice. The use of greenhouse leads to an increase in production per land, water and nutrient units, higher fruit quality, enhance production for each unit of water and nutrient~~,~~ longer production periods, and ability of off-season production. According to Pardosi et al. (2004), Egypt has 1350 ha of polyethylene greenhouses, 50,000 hectares of walk-in tunnels as well as 10 ha of hydroponics systems. Greenhouse production helps to meet the local market needs for vegetables and ornamental plants. Besides supplying the local markets, the production of greenhouses should be greatly valued for its export potential which plays an important role in the foreign trade balance of several national economies in Egypt. However, high relative humidity in air with continuous production under greenhouse creates proper conditions for pests and diseases which could result in an increase in the application of pesticides to protect the crops and the investment. On the other hand, legislative measures and standards requirements of fresh food safety have become increasingly demanding in national and international levels. Food safety issues are the main barriers of export of produce to European Union countries according to the GLOBALGAP legislations (El-Gayar et al., 2019). Egypt's President inaugurated a major greenhouse project to establish 100,000 acres of modern greenhouses in seven new reclaimed areas. The national greenhouse project aims to provide the local market with safe products of fresh fruits and proper quantities of organic products, as well as enhancing the agricultural production of land and saving water. The pressure of increased competition among many countries and the import restrictions imposed by the European and some other countries have intensified the development of greenhouse production in Egypt and other Mediterranean countries. Protected cropping was introduced in Egypt as a technique of production in 1980 and has rapidly expanded in the last three decades. The goals behind this expansion were to enhance the off-season production of vegetables and fruits, to produce earlier than open field crops and to improve the yield and quality of the agricultural products. This article presents a brief review of the greenhouse best practice in Egypt.

2 DOMINATED CLIMATE IN EGYPT

Egypt is subjected to a Mediterranean climate characterized by variability in the air temperature. It has been divided into several agro-climatic regions according to the average temperature values. The most important agro-climatic regions are the Nile Delta; and Middle and the Upper Egypt region (Farag et al., 2014). Due to mismatch of the borders of the governorates inside these regions with the latitude lines, we can characterize the approximate location of Upper Egypt region between (24^oN – 28^oN), Middle Egypt region between (28^oN – 30^oN) and Delta region between (30^oN – 31^oN).

Generally, the climate in Egypt is characterized by a dry summer season associated with low precipitations and high temperatures and a winter season with light rain. Rainfall gradually decreases with the latitude, from the North to the South (Abdrabbo et al., 2012). The influence of the altitude on the rate of rainfall is also considerable since the rainfall increases on high mountains on the red sea coastal area and Saint Catherine Mountains. Table (1) presents the average climatic data including air temperature (average, maximum and minimum), relative humidity, wind speed, rainfall, and evapotranspiration. The data show that lowest maximum and minimum air temperatures occur during December and January; temperature gradually increases from February to reach the highest average temperature during June and July (**Saleh et al., 2017**). Evapotranspiration follows almost the same trend as air temperature. Air relative humidity increases during January to reach about 70%, decreases from April to about 50% and then increases again during August until December.

3 CURRENT STATUS OF THE GREENHOUSE STRUCTURE AND COST

The traditional greenhouse structure in Egypt is a single span greenhouse with dimensions 40 m length, 8.5 m width, and 3.3 m height. The single span structure is considered a “walk-in” greenhouse. There are many other structures that were developed in Egypt during last 25 years. The most popular structure is a double span structure. Growers in Egypt have found that double span has a better structure as it has better ventilation and easier management, especially in case of using machines to prepare the land for greenhouse construction and operation and harvesting of vegetable fruits (see Table 2). With the start of high investment projects from the private sector by the middle of the 1990s, the multi-span greenhouses started to be used as they are not suitable for the small or moderate size growing firms. During the last fifteen years, the Parron system, which uses for support of grape trees, was transferred to the protected agriculture sector by another design (see Fig. 1). The wooden greenhouse uses the same structure with greater height and more ventilation. The farmers adopted this technology for vegetable and tropical fruit production. This structure is more attractive than the steel structure due to its low cost. With similar protection for the cultivated crops, the cost of wooden greenhouses is five-times lower than steel greenhouses. Although the durability of wooden greenhouse structure is less than steel, it reduces the capital cost for the grower, which can encourage new investors to adopt such structure.

During the 1980s, the cultivation under protected greenhouses and low tunnels shifted activity from traditional systems to a modern intensive one. The intensive agriculture using modern technologies includes greenhouses, new cultivars, and verities with high yielding as well as new fertilizers and agricultural chemicals. The pressures exerted on the developing countries natural resources created environmental hazards such as soil fertility degradation and groundwater pollution by nitrates and pesticides which are typical consequences of this agricultural intensification (**Abou-Hadid et al., 1993**). Therefore, good management of modern protected agriculture is one of the most important options in the Mediterranean countries such as Egypt which need to improve the productivity from the agricultural sector to meet the gradually increasing demand for food for the increasing population and conserve the natural resources and environment. The present work provides information and some suggestions and measures that can be used by farmers to better manage the greenhouse production under environmental control systems.

4 CULTIVATION OF TROPICAL FRUITS UNDER SCREENHOUSE

Greenhouses covered by screen nets or shade nets are widely used in Egypt to reduce the radiation intensity in the greenhouse, especially during hot summer days. The reduction of air temperature under screen net cover depends on the shading factor of the material. Screen shade net can be applied outside on top of the greenhouse (using proper construction) which will be more effective in reducing the heat load of the crops cultivated under the greenhouse. However, the screen net should consider a good cover which permits sufficient ventilation through screen openings.

Medany *et al., (2009)* conducted a study on the effectiveness of a white screenhouse for growth of mango Keitt cultivar. They found that the maximum air temperature under screenhouse was 2°C lower compared to the open field conditions during the summer season because of lower interception of solar radiation. The minimum air temperature took another trend; minimum air temperature under screenhouses was 1°C higher than in the nets because of the greenhouse effect of the cover material (Abulsoud et al., 2014). The average air relative humidity was increased under the screen net by 4-8% compared with ambient conditions. The increase in the air relative humidity can be associated with the use of the white net cover. On the other hand, **Hasanein *et al*. (2014)** reported that evaporation under the net house was lower than outside. The three major factors affecting evaporation are: (a) wind speed is lower under the screenhouse compared to outside; (2) interception of solar radiation is lower under the net house and (3) air relative humidity is higher which reduces the evaporation under the protection of white net.

5 VEGETABLE CROPS

Vegetables are of essential importance for food security in Egypt. Egypt is self-sufficient in most of vegetable crops. The sector regenerates a high added value in the Egyptian financial statement through meeting the demand of Egyptian people from the variety of vegetable species and exports to European countries, Arabian Gulf, and Africa.

Given the relatively high investment and operational costs of a greenhouse production system, only high-value crops will result in a viable business case. Vegetable crops such as tomatoes, cucumbers, peppers, peas, and other field vegetables are the main greenhouse horticulture crops; and recently, higher value crops such as broccoli, lettuce and other new species have been introduced especially for modern greenhouses which use soilless culture techniques. Also, the acreage of flowers can be increased to supply, for instance, the urban market. Other crop options include celery, sweet fennel, and lettuce. An interesting option is the production of high-quality seedlings and grafted plants for domestic use (**Sabir and Singh 2013**).

Vegetable fruit crops were the earliest to be grown in Egypt under greenhouse. After ten years from the introduction of this technology in Egypt, production of fruit trees seedlings under greenhouses started by the mid of 1995s such as banana, orange, and citrus. The area of organic vegetables under greenhouses in Egypt does not exceed 500ha. The protected crops include cucumber, tomato, pepper, zucchini, eggplant, and green beans, among others (Hanafi & Kenny, 2001). Data in Table (3) show the most commercial cultivated crops under greenhouse during the year and their daily irrigation water requirement.

6 SELECTION OF SITE LOCATION

Selection of a proper site for greenhouse construction is considered the first step for sustainable greenhouse production. The main factors determining the proper location and site selection of a greenhouse production area are cost of production, quality of the produced yield, and cost of transportation to targeted markets. Cost and quality of vegetable fruits are dependent on the prevailed climate and the greenhouse growing conditions. The level of investment in technology, depends primarily on the prevailed climate in the concerned area (**Castilla et al., 2004**). The national project of 100000 acre greenhouses considers different criteria of site selection. Most of the sites are in the desert (new reclaimed areas). However, some sites were selected close (60 to 70 km) to the highly populated residential areas to enable the development of new communities around the greenhouse sites, helping with redistribution of the population to the desert areas (**Abdrabbo et al., 2012**).

7 CLIMATE UNDER GREENHOUSES

Greenhouse design in Egypt should manage the high daytime temperatures during summer, low nighttime air temperatures during winter and low air humidity especially in the south of Egypt during the whole year due to the higher temperatures in the south of Egypt (**El-Afandi and Abdrabbo., 2015**).

Under Egyptian climatic conditions, the high daily air temperature occurs for the large part of the year; therefore greenhouse design and operation have to deal with these climatic conditions (**Zakher and Abdrabbo, 2014**). The high air temperature during summer season has led many protected cultivation growers to avoid this by not cultivating any crops in the period from May to August. Such management declines the yearly productivity of the protected cultivation units. The cooling of the greenhouses during most of the year is commonly accomplished through ventilation which can be applied in many ways including natural ventilation that depends on the natural movement of air for reducing greenhouse temperature around cultivated area (**Abou-Hadid et al., 1995**). The natural ventilation of greenhouse is installed on the sides with nets, as well as one or two-sided ventilation openings on the top. The top openings can be flexible to allow it to open or close according to weather conditions. Fogging can be applied for cooling and increasing air relative humidity inside greenhouses. It is useful to relieve peak temperatures during hot summer days. Applying a fogging system can also reduce crop evapotranspiration, but the total water use may be the same because fogging itself requires water (**Abulsoud *et al*., 2014**).

8 SOILLESS CULTURE IN EGYPT

Though the soil is still the main predominant growing medium in Egypt, continuous cropping in open field or plastic houses results in soil-borne diseases. This problem is difficult to solve in plastic houses using conventional rotations because the plastic house is a high investment facility and should not be used to grow low value crops such as onion, carrot, and cabbage. Tomato, cucumber, pepper, eggplant, and melon can achieve good returns, but these crops require plant rotation. As a result, protected cultivation for vegetable production in the greenhouse should gradually change from soil to soilless systems. The need for soilless culture systems does not only depend on the green house, but also the use of soilless culture in open field becomes much more urgent especially when relating to the water subject, fertilizers and pesticides use efficiency. Different systems were developed in Egypt for simplifying the soilless culture techniques to be implemented by householders as well as small farmers. The production of fresh vegetables from roofs of buildings has been applied in Egypt from 20 years ago by a team of Egyptian researchers belonging to Central Laboratory for Agricultural Research Center and Ain Shams University Under FAO umbrella to accomplished a project titled "Green Food from Green Roofs (GFGR) in Urban and Peri-urban Environments in Egypt" TCP/EGY/0166(A), FAO, UN. This technique is still applied by many private companies that are working on establishing and managing soilless culture systems above the roof of buildings. They developed different simple systems to apply in the roof of the buildings in Cairo and Alexandria. On the other hand, the commercial soilless greenhouse culture in Egypt began slowly in the last two decades. Commercial farms are less than 2 % of the total cultivated area using different soilless culture systems. Deep water culture is a technique which is most widely used in Egypt. Nutrient film technique is used via "A" shape of pipes. Until now, the use of proper soilless culture has not received enough attention from the growers except the growers who provides leafy crops for large restaurants, hotels, and hypermarkets. Researchers in Egypt have been in the forefront of this field from the beginning of 1990s.

Some researchers have investigated the integrated management of the vegetable crops cultivated in soilless culture. **El- Beltagy et al., (1992)** reported that vegetative growth rate of some vegetable plants has different trends according to substrate media used. Cucumber is grown in peat moss +sand +vermiculite (1:1:1) substrate mixture and yields a higher vigorous plant compared with other substrates mixtures. **Medany et al. (1995)** also investigated using local substrate materials for producing vegetables in Egypt. They used a date - palm fibers (Leaf) dried shredded date - palm leaflet fibers, nylon threads, rockwool, and the control "cultivate in soil". They reported that the leaf and palm leaflet fibers treatments gave 50 % higher cucumber yield than the rockwool media and 100 % higher than the control. They also reported that the increase of the yield with the reduction of production cost by changing the expensive imported rockwool which led to make the palm fiber reasonable alternative local media substrate for growing vegetable plants. **AL-Harbi et al., (2006)** studied different reates of nitrogen with head and romain lettuce grown in coconut fiber, and found that increase in nitrogen rate led to increase in the fresh weight of lettuce whereas nitrate concentration in the lettuce leaves will increase the nitrogen doses. **El-Sayed et al. (2016)** used different substrates and nutrient solutions for vegetative growth, mineral content, production, and fruit quality of strawberry production. The authors used three substrate mixtures including perlite:peat-moss (1:1 V/V) M1, perlite:plant compost (4:1 V/V) M2, and perlite: vermicompost (4:1 V/V) M3, while the three nutrient solutions were vermicompost-tea, animal compost-tea and mineral nutrition (control). The highest significant values of vegetative growth, yield and its component, fruit quality and chemical characteristics were recorded for plants grown in perlite: peat-moss mixture and fertigated with the mineral nutrient (control), while plants grown in perlite: vermicompost mixture and with animal compost-tea as nutrient showed the highest values of fruit firmness, TA and heavy metals. Finally, several works have been conducted under Egyptian conditions which are now for commercial use. There has been significant amount of work in agriculture in Egypt and the use of different soilless techniques and different nutrient solutions based on crop age, season, etc is well established.

Cucumber is one of the major crops which requires warm temperature to grow and gives good yield (Abdrabbo, 2001). Most of cucurbitaceous vegetables grow in warm temperate and cool tropical climate. The optimum daytime temperature ranges between 22^{o}C and 30^{o}C **(Grubben, 1997)**. On the other hand, **Papadopoulos et al., (2000)** studied the effects of daytime and nighttime air temperature on growth of cucumber during the spring season. They indicated that cucumber growth rate was increased linearly with increasing average daytime air temperature. Also, the authors added that plant growth and development rates were increased with increasing air temperature regardless of daytime temperature or nighttime temperature. Abdrabbo et al. (2010) reported that the cover soil with transparent mulch led to higher soil temperature, which in turn resulted in increasing plant growth rate and yield. Air temperature fluctuations in subsequent years modify the course of the occurrence of phenological phase dates and, thus, affect the size and quality of the yield of crop plants **(Ahmed *et al*., 2004). Farag *et al*. (2010a)** studied the effect of different periods for covering the low plastic tunnels on average air temperature under unheated greenhouses. The authors reported that covering the growing beds with white polyethylene significantly and consistently raised air and soil temperatures compared to untreated beds. The highest air temperature was obtained by plastic tunnel treatment. Using polyethylene tunnel inside the unheated plastic house during the cold days increased the air temperature by about 1-1.5^{o}C compared with plastic house weather; while air temperature inside the plastic house was increased about 1.5-2 ^{o}C above the temperature outside green-house during the daytime (**Zakher and Abdrabbo., 2014**).

Air relative humidity is the ratio of the actual air vapor pressure of water vapor to the air vapor pressure of air saturated with moisture at the same temperature. Relative humidity affects plant transpiration by affecting the air vapor pressure difference between plant leaves and surrounding air **(Abdrabbo *et al*., 2009).** A relative humidity (RH) at 75% is considered to be optimal under plastic greenhouses. Sufficient relative humidity would help to produce good quality fruits without coloring defects **(Bakker *et al*., 1995)**. Relative humidity under plastic cover or under screen net is higher than the open field by different amounts, depending on several factors **(Medany et al., 2009)**. Air relative humidity increases under the polyethylene houses, not only because of the polyethylene cover but also due to the vegetative mass of the plants which grow inside the house **(Abou-Hadid *et al*., 1988)**. Relative humidity increases according to the shading density; a higher shading density would lead to a higher air relative humidity **(El-Gayar et al., 2019)**. Local studies under Egyptian conditions of single typical polyethylene house with side and top ventilation has shown that permanent natural ventilation, by opening the windows during the nighttime during spring and summer seasons, reduced relative humidity inside the greenhouse, and it also affected other climatic variables that enhanced crop productivity **(Farag et al., 2006).**

Polyethylene mulching under greenhouse has some effects: it increases soil temperature, conserves soil moisture, and inhibits weed growth (**Hanada and Adams 1991**). **Abdrabbo et al. (2010)** reported that transparent and/or black plastic films created favorable conditions for increasing soil temperature compared to the soil under greenhouse without mulch cover. They added that the soil temperature was by 2–3 °C higher under clear polyethylene mulch. A significant difference in plant growth characteristics under mulch was reported for pepper and eggplant which grow under greenhouses by enhancing the water and fertilizers availability in the plant root zones (**Farrag et al., 2016, and Abou-El-Hassan et al., 2014**). **Farag *et al*., (2010)** studied the effect of different mulches of growing beds. The data obtained showed that the highest vegetative growth characters were obtained when the growing beds were mulched. On the other hand, the lowest vegetative growth characters were obtained when growing beds without mulching (control). Putting a clear mulch on the growing beds gave a significantly positive effect on stem diameter when compared with plant on the bed without mulch. **Farag *et al*., (2010)** measured the air temperature under a covered tunnel which was constructeded under unheated greenhouses. The authors found that air temperature under clear mulch increased about (1.5-3 ^{o}C) more than the control. The results showed that air temperature under the covered tunnel was higher than the other treatments. The clear mulch gave the highest soil and air temperature followed by without soil mulch in comparison with the other treatments.

9 IRRIGATION REQUIREMENTS UNDER GREENHOUSES

Drip irrigation is the main irrigation system which is used under greenhouses in Egypt. The calculation of the daily irrigation requirement for cucumber under greenhouse in Egypt is illustrated in Table (4) as an example for the irrigation schedule using drip irrigation in greenhouses under Egyptian conditions based on climatic data. Many researchers studied the irrigation management under greenhouse in Egypt and Mediterranean. EI- Karam *et al*. (2002) studied the effect of different irrigation levels (100%, 80%, and 60% of ETc) on lettuce plants. The results showed that water stress caused by the deficit irrigation levels significantly reduced leaf number, leaf area index, and dry matter accumulation. Several ~~totally~~ mature leaves reached harvesting time in the 80% and 60% treatments were 8% and 14% lower, respectively than the control treatment. **Abdrabbo *et al*. (2009)** applied different polyethylene mulch colors and irrigation levels on cucumber plant under polyethylene greenhouse. The 0.80 ET_c treatment produced the highest vegetative growth and production. 1.00 ET_c came in the second order followed by 1.20 ET_c, while 0.60 ET_c produced the lowest vegetative characteristics. **Singer *et al*. (2003)** studied water-stress treatments on growth stage and production of snap bean. They found that vegetative growth represented by plant height and number of leaves was significantly reduced by water-stress treatments. **Wang and Zhang (2004)** studied the effect of different irrigation water treatments on plant growth of cucumber in greenhouse and found that water supply was one of the most common limiting environmental factors for plant growth. Deficit water budgets lead to numerous physiological changes, such as altered root to shoot ratio, reduced leaf area or number of leaves, and finally reduced leaf area index. **Gaafer and Refaie (2006)** investigated the effect of different irrigation regimes (80%, 100%, and 120% of ETc) on cantaloupe. The results showed that water stress significantly reduced plant height. The highest irrigation levels (120% of ETc) increased plant height. **Abdrabbo *et al*., 2009** found that the mulch colors and irrigation levels significantly affected plant height in the two growing seasons. 0.80 ET_c treatments produced the highest vegetative characteristics. 1.00 ET_c came in the second order, followed by 1.20 ET_c, while 0.60 ET_c produced the lowest vegetative characteristics. The results also indicated that transparent polyethylene mulch resulted in the highest vegetative characteristics followed by black mulch. The lowest plant height, number of leaves, and total leaf area were obtained by no soil cover (control). **Abdrabbo *et al*. 2010** studied the effect of different irrigation regimes on vegetative growth of eggplant and found that the irrigation level 1.00 ET_c recorded by far the highest vegetative growth followed by 1.20, 0.80 and 0.60 irrigation levels in both seasons. Vegetative growth under a black net was significantly higher than that under a white net in both seasons; the lowest plant length was recorded under open field conditions. The interaction between greenhouse cover and irrigation level showed that the highest significant value was for 1.00 irrigation levels, with a significant difference between greenhouse cover, while the lowest value was obtained for 0.60 irrigation level under open field conditions in both seasons.

10 GREENHOUSE TECHNOLOGIES AVAILABILITY IN EGYPT

The availability of the greenhouse technology is not a critical issue for the small farmers who use small greenhouse with a simple technology to produce some vegetables such as cucumber, tomato, eggplant, Okra and Molokhia for the local market during winter season by using polyethylene greenhouses to make a significant profit. The big investors in Egypt who are looking for new technologies such as environmental control, soilless culture techniques and the new species and varieties which the consumer in Egypt or outside are looking for. As mentioned above, the soilless culture technology is available in Egypt, especially for leafy crops (such as new varieties of lettuce, celery, among others) with a good profit margin for the greenhouse sector. The soilless culture in Egypt still suffers from missing automation technology for monitoring the quality of water and modifying the nutrient solution. There have been some efforts to address these issues but, until now, there are no significant improvements in the field. The second real challenge for expansion of soilless culture in Egypt is the availability of the market; regular local market does not recognize the differences between the production from soilless culture techniques and conventional farms. The production cost from soilless culture is much higher compared to the traditional production process, while, the price of the both products is always the same in the wholesale markets. The same is true for the environmental control; many growers use shading net with fogging system for production of leafy crops during the summer season for continuous supply of large hotel, restaurants and hypermarkets but the manufacturing technology of environmental control inside Egypt is still not well developed. In this aspect, agriculture sector needs an integrated cooperation with the other scientific communities such as engineering and electronics sectors to produce a prototype of local integrated system to produce local environmental control greenhouses.

11 GREENHOUSE TRANSFER TO EGYPT

Egypt imported a variety of greenhouses from highly developed countries in greenhouse technology such as the Netherlands, Spain, China and Hungary in the national project for 100000 greenhouses. The decision makers in Egypt studied the suitability of these greenhouses for Egyptian conditions based on the experience of the agriculture sector in imported greenhouse structures. Most of the greenhouses which were imported during the last ten years have a moderate or simple technology which is easy to construct, install, and maintean at reasonable cost according to the production plan. The Egyptian decision makers learn the lesson of transfer the greenhouse technology from the Northern Europe countries during 1980s which was suitable for cold weather with poor natural ventilation. All of the imported technology for governmental or for private sector, even the local manufacturing, concern about good ventilation system of the new greenhouses because the cold weather in Egypt is only during December, January until mid February (Table 1) which means a short cold season with long hot season which need good ventilation and good protection from high temperature during the summer season.

Table 1. Forty year average~~of~~ climatic data for Zagazig as a sample of the climatic data in the Nile Delta region (Source: Central Laboratory for Agricultural Climate)

Month	Temperature			Humidity	Windspeed	Sol.Radiat.	Rainfall	ETo - Penman
	Aver Temp	Max Temp	Min Temp	%	km/day	$MJ/m^2/day$	(mm)	mm/day
Jan.	13.20	19.70	6.60	71.00	136.00	12.10	6.70	1.70
Feb.	14.10	21.00	7.10	66.00	139.00	14.90	5.60	2.20
Mar.	16.40	23.60	9.20	62.00	139.00	19.30	3.80	3.20
April	19.80	27.60	12.00	55.00	168.00	23.20	2.00	4.50
May	23.50	31.40	15.50	50.00	163.00	26.20	2.60	5.60
June	25.30	35.00	18.60	52.00	151.00	28.90	0.00	6.30
July	27.30	37.40	20.20	59.00	124.00	28.10	0.00	6.10
August.	26.30	34.20	20.40	64.00	96.00	25.90	0.00	5.40
Sept.	25.60	32.50	18.60	65.00	99.00	22.80	0.00	4.50
Oct.	23.40	30.20	16.60	65.00	124.00	17.90	1.80	3.50
Nov.	19.40	25.70	13.00	69.00	104.00	13.40	4.30	2.30
Dec.	14.90	21.20	8.60	73.00	124.00	11.40	6.10	1.70
Average	21.10	28.00	13.90	63.00	131.00	20.30	32.90	4.45

Table 2. Different structures of greenhouses and total cost for each unit*

	Greenhouse type	**Dimension (m) (Length – width – height)**	**Total cost (L.E.)**	**Cost for square meter**
1	Single span	40 x 8.5 x 3.30m	36000	100
2	Double span	40 x 16 x 3.25m	80000	120
3	Double span	30 x 16 x 3.30m	75000	130

4	Multi span	40 x 104 x 4m	400,000	96
5	Wooden GH	64 x 140m	200,000	22
6	Single span (Nursery)	30 x 8.5 x 3.3m	56,000	220

* Source: greenhouse sector- Agriculture Research Center, Ministry of Agriculture and Land Reclamation.

Table 3. Common crops under greenhouse in Egypt, life period for each crop, average irrigation requirements, and cultivation season based on Delta region.

Crop	Life period /days	Average irrigation requirements (L/m^2/ day)	Suggest growing season
lettuce	70 - 85	10	Summer
Celery	75-90	8-10	Summer
Red cabbage	90 - 110	7-9	Winter
Tomato	240-300	8-16	winter
Pepper	120-160	8-12	winter
Squash	75-100	8 – 10	All year
Broccoli	80-100	8-10	Winter
Dwarf Mango	Perennial	6-14	All year
Cucumber	90-120	4-12	winter

Table 4. Irrigation schedule for cucumber under greenhouse in the Nile Delta region during the autumn season.

Week	ETo GH	Kc	ET crop	+ leaching req.	IR (L/ Plant/ day)	period Minute
1	5.5	0.45	2.48	1.55	0.87	26
2	5.1	0.52	2.67	1.84	1.03	31
3	4.9	0.58	2.85	2.14	1.20	36
4	4.8	0.64	3.04	2.47	1.39	42
5	4.3	0.70	3.00	2.63	1.48	44
6	3.9	0.77	3.02	2.83	1.59	48
7	3.5	0.85	2.97	2.97	1.67	50
8	3.2	0.92	2.93	3.29	1.85	56
9	3.1	1.10	3.37	3.80	2.14	64
10	2.9	1.11	3.26	3.67	2.06	62
11	2.9	1.01	2.89	3.26	1.83	55
12	2.8	0.96	2.68	3.02	1.70	51
13	2.7	0.95	2.59	2.91	1.64	49
14	2.6	0.94	2.49	2.80	1.58	47
15	2.6	0.94	2.46	2.77	1.56	47
16	2.2	0.80	1.78	1.11	0.63	19
17	2.1	0.65	1.35	0.93	0.52	16
18	1.9	0.50	0.96	0.72	0.41	12

Figure1. Cultivate vegetable crops under wooden structure greenhouse (Private farm – Cairo – Alexandria Desert Road)

Figure 2. Mango under wooden greenhouse structure (El-Bosaily Farm – Behira Governorate– Agricultural Research Center).

Figure 3. Hydroponics in a commercial farm in Egypt - location Cairo, Alexandria Desert Road.

12 CONCLUSIONS

Protected cultivation of horticultural crops in Egypt has had significant development in many aspects. The national project to establish 100000 greenhouses has been one of the major motivations to improve the protected cultivation sector during recent years. There have been significant trials for both commercial and research sectors in terms of improving greenhouse production and using new technologies such as soilless culture at commercial scale. Improving the knowledge of the people who work in this sector is the real challenge which protected agriculture faces with availability of new technology and advanced techniques. The current work is one of the practical trials for improving knowledge of this sector for short term. Further scientific studies are needed for every subject mentioned in this paper such as simple estimation of irrigation schedule (using Excel sheet), tricks of using soilless culture technique, climatic study of the microclimate under white screen net in different climatic regions in Egypt and growth, productivity and economic feasibility of major vegetable crops under modern greenhouses for local market and exportation.

13 RECOMMENDATION

The current work demonstrated some of good management practices related to production under various greenhouse structures in terms of selection of appropriate site location, irrigation water management, proper climate conditions under greenhouses, and proper management using soilless techniques. Enhancing the food safety under greenhouses will help to meet legislation of EUREPGAP and open the window to export bigger volumes of excess greenhouse production of vegetables and fruits to European countries. Food safety is related to all elements of greenhouse management such as, greenhouse structure, ventilation, cover material, seed and rootstocks, irrigation management, fertilization management and pest and disease control. The integrated crop management for all stakeholders of greenhouse sector is a vital need for improving food safety of produced vegetables, fruits and leafy plants.

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