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Full Length Research Paper

Status of greenhouses in Eastern Mediterranean coastal areas of Turkey

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The study was carried out in greenhouses at Eastern Mediterranean coastal areas of Turkey in Samandag area of Hatay province where greenhouse production is wide spread. The work undertaken in 2007 aimed at determining general management problems, structural features and weaknesses and climate control of greenhouses owned by villagers, having only small holdings barely adequate for supporting their families. 97 greenhouses in 48 holdings were evaluated. Only one greenhouse was glass and the rest was plastic covered. The greenhouses with an area of greater than 1000 square meter were 32%. Regarding roof structures, 63.9% was of arch, 34.0% shallow arch and the remaining 2.1% was of gothic. The single glasshouse that existed in the area had saddle roof. The roof structures did not generally have adequate slopes. The plastic cover material used was mostly PE (79%) with inclusion of UV+IR. Heating of the greenhouses was only for frost protection purpose which adversely affected crop yields and quality. Only 2% of the greenhouses present in the area was constructed based on projects of engineering designs; the remaining were simply of palliative construction with no expert input. They were usually constructed by growers themselves. Interviews with growers showed that they were quite knowledgeable on best management greenhouse practices; however, the economic constraints prevent them from using and adopting new greenhouse technologies. There was only one greenhouse where soilless practice was used. The survey work showed that major improvements regarding types, construction, climate control of greenhouses and crop production methods were essential to improve greenhouse production in the area.

Key words: Greenhouse, climate control, greenhouse construction.

INTRODUCTION

Presently, needs for agricultural products are increasing with increase of population. To this effect, greenhouse food production is an additional alternative for meeting increased food demand year around. All plant growth factors can be controlled and maintained at optimum level year around in the greenhouses where one can freely move around and use agricultural machinery (Zabeltitz, 1986). The greenhouses facilitate extending of growth period and therefore multiple annual cropping becomes possible. Additionally, the areas which are not suitable for open field agricultural practice can be utilized for greenhouses. Continuous agricultural production is possible for meeting market demand. Not only high crop yields but also high quality crops can be produced in greenhouses. Labor demand of greenhouses is long term, mostly year around, not seasonal as the case for open-field cropping. Extension of greenhouse cropping supports the development of new branch of industrial sectors producing greenhouse materials (Yuksel, 2004).

Microclimate suitable for the greenhouse cropping starts at Yalova region, in the North and extends to Antalya, Mersin and to Samandag, in Hatay province in the Southern Turkey (Ones, 1990; Olgun et al., 1997). According to data of 2001, 96% of protected agriculture (i.e., plastic tunnels and greenhouses) exists in the Mediterranean and Aegean regions. High vegetable production under protected agriculture in the Mediterranean and Aegean regions is result of the fact that cropping is possi-

Abbreviations: PE, Polyethylene; **UV**, Ultraviolet; **IR**, infrared.

ble all year around and the existing climate is most suitable for the protected agriculture (Anonymous, 2001). Samandag in Hatay region has the fifth rank of importance in Turkey for greenhouse production and protected agriculture (Anonymous, 1997).

Samandag County lies on the most Eastern area of the Mediterranean Sea cost line in Turkey and has rather unique microclimate suitable for greenhouses. If greenhouse production potential of the county could be utilized, it would benefit economically both the country and the Samandag area. The area which is at Southern border of Turkey has good infrastructure regarding roads, air transport and shipping to Middle Eastern countries, and therefore it has great potential for export which would create additional advantage of improving greenhouse cropping (Bozkurt et al., 2006).

Greenhouse frames and structural elements are considered expensive when considered with rather low incomes of the growers in the area. Therefore it is essential that they should be constructed based on well designed projects so that they can be used for long periods. Because of wrong designs and faulty construction, numerous problems are evident in greenhouse cropping (Tekinel and Baytorun, 1990). The structural problems of greenhouses in Turkey are not uncommon. The design criteria used do not adequately consider climate and likely crops to be grown in the greenhouses. Therefore the greenhouses seen in the area are technically inferior; the designs used do not consider climate, and thus they allow limited usage of agricultural machinery in addition to having numerous other problems limiting good quality high crop yields (Saltuk, 2005).

Cemek and Demir (1997) showed that most of the greenhouses in Black Sea region of Samsun, Ordu, Giresun and Amasya were poorly designed and constructed. Briassoulis et al. (1997) investigated project design standards and characteristics of greenhouses in European Union, including greenhouse roofing and columns, characteristics of covering material, joints of structural elements, loads on roof and side walls and different types of constructions. Their work listed many problems associated with plastic materials used in the greenhouses, like high labor costs of in placing and changing plastic cover materials, easy deformation and breaking of plastic structural elements during usage. They made recommendations to prevent weakening and thinning of the plastic cover, to ensure tight covering of the plastic material, adequate ventilation, and proper selection of the cover material, correct roof slope and angle to prevent condensation of water droplets under cover material, effective use and long lasting of cover materials.

Problems associated with greenhouse cropping in various areas of the Mediterranean Region in Turkey have been investigated and evaluated by Saltuk (2005), Onder and Baytorun (1999), and Emekli et al. (2007), Canakcı (2005). They listed what should be done for further development and improvement of greenhouses in the region. This work was undertaken with the aims of determining present status and structural problems adversely affecting greenhouse cropping in Samandag County of Hatay Province. It is hoped that criticisms made on present status of greenhouses can be used as guide lines for preventing problems in future advancement of greenhouse cropping in the area.

MATERIALS AND METHODS

The work was carried out in Samandag County of Hatay Province in Southern Turkey of Eastern Mediterranean region. The area is bordering and surrounded by Hatay city in the East, Mediterranean Sea in the West and Iskenderun city in the North. Total area is of 382 000 square kilometers with 31 towns and 12 villages (Anonymous, 1997).

A field survey work was carried out with questions aimed at determining management and structural characteristics, and in-house climate control problems of greenhouses present in the area. The general information on areas with greenhouses and various management problems was gathered from local Agricultural Directorate of the Samandag County.

The equation used to estimate the number of greenhouses subjected to the survey work was given by Gunes and Arıkan (1988) as:

$$n = \frac{N \times \sigma^2}{(N-1) \times D^2 + \sigma^2}$$

where n is the number of greenhouses to be surveyed, N total number of greenhouse present in the area and σ^2 is total population variance. The D^2 is equal to $(d/t)^2$ with d being the deviation from the mean of the order 5%, and t is the table value of 1.96 at 95% confidence of the student t-distribution. Total number of greenhouses to be surveyed was calculated as 97 using the above relation.

Length, side-wall heights, roof height and size of ventilation openings of each greenhouse were measured during survey work. The greenhouse holdings were surveyed and evaluated in two separate groups as (1) small family greenhouses and (2) large size commercial greenhouses. The greenhouses where all the work was carried out by the family members themselves are described as 'family greenhouses'. The greenhouses with outside labour are large size commercial greenhouses. The survey findings were discussed based on general management characteristics, structural features and in-house climate characteristics.

RESULTS and DISCUSSION

General features of greenhouses

Number and size of the surveyed greenhouse holdings are given in Table 1 which showed that 30, 38 and 32% of 97 total greenhouses present in 48 holdings were of the size up to 500 m^2, 501-1000 m^2 and larger than 1000 m^2, respectively. Sevgican (1999) showed that size of greenhouses present in Turkey was in the range of 1000 - 3000 m^2. Seventy six greenhouses visited here were constructed within the last 5 years. It was noted that most of the greenhouses were those which replaced old ones which were constructed earlier rather primitively based on no design criteria at all. Although the newly constructed greenhouses looked well designed, the existing green-

Table 1. Number and size of the surveyed greenhouses.

Greenhouse size (m^2)	Total number of holdings	Greenhouse number
< 500	22	29
501-1000	14	37
1000 <	12	31
Total	48	97

house cropping practice was unfortunately not compatible with the modern and best management. The growers used their own sources for constructing 93.8% of the existing greenhouses, and only the remaining 6.2% used bank loans. The greenhouses were generally family holdings if their management and small sizes were considered.

Large size commercial holdings were 50.2%. The survey work showed that 19.8% of the greenhouses needed no out-side labour and all relevant work was carried out by the family members themselves. Temporary labour use of large size holdings was 73.2% at high season. Only 7% of the holdings used permanent field workers. The holdings which have permanent staff had greenhouses with size larger than 1000 m^2. None of the holdings had either agricultural technician or engineer. They consulted rarely with an agricultural engineer who happened to be around if they had any problem.

There was only one greenhouse where soilless cropping was in practice, among the greenhouses surveyed. Of 35% of the greenhouses, only Fall-season single cropping was used. Both spring and fall-season double cropping were used in the remaining 65% of the greenhouses. Among the greenhouse grown crops in surveyed area, tomato was 91% which was followed with 6% cucumber, and 3% pepper. Country-wide greenhouse grown vegetables in Turkey are 96%, which is followed with 3% cut-flowers and 1% fruits. Among the greenhouse grown vegetables, tomato was in the first rank with 47%, which was followed with 32% cucumber, 9% pepper and 7% eggplants. Fresh beans, melon, squash and other vegetables were added to only 5% (Tuzel et al., 2004). Mulch use was also investigated in the surveyed area, and it was observed that only a small 7.22% of the greenhouses used mulching. Of mulching, half was transparent and the rest was black PE.

Structural characteristics

Of the greenhouses surveyed, 97.9% were constructed using no design-project; only 2.1% of the greenhouses had projects following design-criteria. One of the greenhouses which was constructed using a project was in fact a glasshouse with saddle type roof, built 9 years ago. Another greenhouse which was constructed based on an available project was covered with plastic with gothic type roofing; it was built with loans of World Bank and Ministry of Agriculture, and it was own by grower's cooperative. Greenhouses with no design project are wide spread in other areas with importance of greenhouse cropping. Saltuk (2005) showed that 53.5% of the greenhouses in Mersin Province and the vicinity were constructed by handy man with no need of any project and using materials locally produced. Similarly Gulluler (2007) showed that 62.9% of the greenhouses in Adana area had no project. The greenhouses in Turkey are usually constructed using no design projects, but rather based on visual experience and individual expertise and without proper static and strength analysis; therefore, they either use excess or less material than what actually is needed. If excess material is used, construction becomes costly, and over shadowing interferes good cropping. In the second case of using less material for cutting high costs, the greenhouses cannot stand extreme weathers of high winds and rains. The greenhouses must therefore be constructed based on well design projects with due consideration of static and strength analysis to overcome the mentioned problems (Ustun and Baytorun, 2003).

Greenhouse construction materials

Galvanized pipes, although expensive, were used for most of the greenhouses (98.9%) except one where T and L iron profiles were used. As Onder (1998) showed, the construction materials like iron, wood and galvanized pipes were used either alone or their mixed combinations in construction of greenhouses. It was observed that the growers recently abandoned using wood material in construction because the nails used caused fracturing of the plastic cover. However it was not uncommon to observe the greenhouses where the plastic cover was held in place with nails.

It was observed that no treatment for preventing corrosion of the iron profiles was made. Therefore the greenhouse structure was corroded and thereby the plastic covering was also adversely affected in time. Baytorun (1995) recommended either galvanization or painting the structural material for prevention of corrosion.

Types of greenhouse roofing

The roofing of 63.9 and 34.0% of the greenhouses survey-

Table 2. The covering materials used in the surveyed greenhouses.

The covering material	Greenhouse number	Covered area (%)
Glass	1	1.03
UV added PE	1	1.04
IR added PE	2	2.08
UV+IR added PE	76	79.17
UV+IR+ Antifog added PE	14	14.58
UV+IR+Antifog+antibacterial added PE	3	3.13

ed was respectively arch and shallow arch. The one greenhouse constructed with financial supports of World Bank and the Ministry of Agriculture had gotic type roofing. The single glasshouse existed in the area had saddle type roofing. The roofing angle of glasshouse with saddle type roof was 19.8°C. The roofing angle of the greenhouses with arch type roofing changed within 17-47°C. The angle was 8.5-26.5°C in the greenhouses with shallow type roofing, and it was 26.5°C in the gothic roofing. Alkan (1977) and Yuksel (2004) showed that the best roofing angle of saddle type roofs was 26-27.5°C at which solar radiation loss was limited to only 14%, which was even smaller as 10% in arch type roofs. The growers in the region stated that they preferred arch and shallow arch type roofing for best use of natural light conditions. However, the roofing angles of the single glasshouse and other greenhouse were not compatible with recommended standards.

Greenhouse covering materials

The covering materials commonly used are given in Table 2. The covering was generally of plastic material (%98.97), and only one greenhouse had glass covering. During early phase of the greenhouse cropping, the growers preferred glass covering to ensure good lightning; however, they started using plastic cover with advancement of greenhouse cropping and the related technologies (Baytorun and Kohlmeier, 1990).

Onder (1998) observed that the preference of plastic cover increased among the growers with development of plastic material with special additives to increase their quality. The growers do not use glass covering because of their high initial investments costs. Additionally breaking of the glass material due to consolidation of ground where the greenhouse constructed was common complaint of the growers. The breaking of the glass material in time may be an indication the construction was not properly made.

It was a common practice among the growers (68.75%) to change the plastic covering material every three years. However those growers (15.63%) that own greenhouses close to costal area open to high winds change the cover material every 2 years. The covering material does not last surprisingly any longer than the guaranteed period. It was observed that there was no wind breakers used to prevent easy fracture of the plastic covering in the areas exposed to high winds.

Greenhouse dimensions

The single glasshouse found in the area consisted of 3 blocks of 18.6 m width each, adding up a total width of 55.8 m. The greenhouses with arch and shallow arch roofing consisted of variable number of blocks from single block to as large as 12 blocks. However they generally included either 2 blocks (19.5%) or 3 blocks (42.5%). There were only two greenhouses with 11 and 12 blocks. The roofing width was generally (78.8%) within the range of 5-6 m, and rarely 7.5-11 m. Overall roofing width of the greenhouses surveyed in the area changed within the range of 8 to 56 m. Yuksel (2004) recommended multiples of 3 m as the best width of the greenhouses to facilitate easy arrangement of planting. The recommended glasshouse width must be 9-12 m, and the plastic greenhouses with width of 6-9 m. He had further cautioned that working in the greenhouse of narrow width might be difficult. The greenhouses with better lightning of 6 to 12 m width produce early and higher yield of tomato crop compared to block widths of 3 m (Germing et al., 1963). However the greenhouses with 3 m-width blocks produce higher profits if one considers high initial investment costs of the greenhouses with wider blocks (Kostelijk, 1962).

When the lengths of greenhouses were examined, it was noted that the single glasshouse found in the area was 60 m in length; whereas the lengths of plastic covered greenhouses showed wide range of differences from 11 to 100 m. Gunay (1980) recommended that the ideal greenhouse length must be within the range of 50 to 100 m. It should be noted however that the greenhouses with high lengths may have ventilation problem in the central areas. The ventilation facilitated through entrance doors of long-length greenhouses may adversely affect plant development because the air entering from the door may reach to high speed (Yuksel, 2004).

When side-wall heights are examined, 37.08, 58.8 and 4.12% of the greenhouses surveyed had wall heights of 0-2 m, 2-3 m and larger than 3 m heights, respectively. It was recommended that the greenhouses used for vegetables had wall-heights of 2 to 3.5 m (Yuksel, 2004).

Table 3. Placement of ventilation windows which changes depending on the cover material used.

Greenhouse type	Placement of ventilation windows							
	4 at side walls		2 at long walls		Roof+2 at long walls		Front roof+2 at long surface	
	Num.	%	Num.	%	Num.	%	Num.	%
Glasshouse	--	--	--	--	1	1.03	--	--
Plastic Greenhouse	56	57.73	12	12.37	3	3.09	25	25.77
Total	56	57.73	12	12.37	4	4.12	25	25.77

The wall heights may change depending on climate also as 2.00 to 2.25 in cold weather, 2.20 to 2.50 m in warm weather, and 2.50 to 3 m in hot climates (Yuksel, 2004). The recommended range of side wall-heights is 1.8 to 3 m (Ones, 1990). The side wall-heights of 62.92%, the surveyed greenhouses were within the recommended range of heights.

The ridge heights of the surveyed greenhouses showed wide range of variability. The greenhouses with ridge heights of 2-3 m, 3-4 m and higher than 4 m were 8.25, 75.3 and 16.5%, respectively. The greenhouses with ridge heights of 4 m and higher had the base area of 0-500 m^2. The growers stated that they preferred high ridge heights to facilitate better ventilation in small size greenhouses.

Greenhouse climate

Ventilation

The ventilation of the greenhouses surveyed was natural and no equipment was used for this purpose. The placements where ventilation windows are installed are shown in Table 3. The ventilation windows of the plastic greenhouses were sited as 57.73, 12.37, 4.12 and 25.77% respectively at 4 side-walls, 2-long side walls, 2-long side walls plus at roof and at 2-long roof surfaces. The greenhouses with full ventilation set ups along the roofing were only 4%. The ventilation sites of the glasshouse were at roof and along 2 long side walls (Table 3).

It was noted that the glasshouse had a special mechanical gear for controlling ventilation. Only one of the plastic greenhouses had automatic control of ventilation. An iron rod was used for manual opening of the ventilation windows sited at side walls in all other plastic greenhouses. The growers had no idea of hygrometers considering that only 9.28% of the greenhouses had hygrometer.

The ratio of the ventilation opening to the greenhouse base area was also examined. The ration was less than 15%, 16 to 20%, 21 to 30% and higher than 30% respectively in 14.43, 27.84, 32.99 and 24.74% of the surveyed greenhouses. The greenhouses with the ration greater than 30% were those having the least base area. Zabeltitz (1990) showed that the ventilation opening ratio of the greenhouses in the Mediterranean Region was 18 to 25%. Genc (1981) and Baytorun (1986) recommended that the ratio should be within the range of 16 to 20% for adequate ventilation in the greenhouses with natural ventilation set-ups. It was therefore noted that only 27.84% of the surveyed greenhouses had adequate ventilation. Because the area where the survey was carried out had high winds, the greenhouses without roof ventilation had adequate ventilation if the ratio was within the required range. The greenhouses without roof ventilation had water condensation on the inner surface of their plastic covering if the ventilation ratio was less than 15%. This situation caused spread of the diseases due to high humidity. Bozkurt et al. (2006) showed that the roof and side-wall ventilation were essential to eliminate high humidity and to lower high temperature in the greenhouses in Samandag County. Yuksel (2001) earlier showed that the greenhouse ventilation was not sufficient if the greenhouse lacks the ventilation in the roof.

A study by Onder (1998) showed that none of the greenhouses in Samandag County had roof ventilation set-ups. Similarly half of the Kumluca greenhouses in Antalya Provinence had no roof ventilation and therefore they had wide spread of fungal diseases resulting from high humidity and temperature (Emekli et al., 2007). The existing situation also caused significant decrease of crop yields, most probably due to decrease of light transmittance of the plastic cover material.

Additional problem noted in the surveyed greenhouses was that the ventilation windows could not properly be closed thus caused loss of greenhouse heating. Mackroth and Struck (1980) showed that preventing leakage on the sides of ventilation set-ups in an old greenhouse can decrease as much as 11% of the heating requirement.

Heating of the greenhouses

Heating of all the greenhouses in the Samandag County had only a single purpose of frost protection. Use of proper management technology in the greenhouses of the area was limited, and crop production could only be sustained with simple and palliative measures, like heating done only for frost protection (Tuzel et al., 2004). Baudoun and Zabeltitz (2002) showed that heating was essential to sustain high and good quality crop production when and if the temperature in greenhouses fell below 12°C. Long years of mean greenhouse temperatures in December, January and February in Hatay Province were

below 12°C, and thus the heating of the greenhouses would surely benefit the cropping (Onder, 1998).

Heating of greenhouses with thermometers (95.88%) was started if the temperature decreases to 2°C. Decision for heating was simply based on weather forecasts and weather observation of growers themselves if no thermometers existed in the greenhouses. As heating systems, 23.96, 47.92 and 28.12% of the greenhouses respectively had stove with gas tubes, wood burning stove and combination of wood burning and gas tube stoves. The various fuels used in stoves, other than wood, were coal, olive oil residue cake and used-motor oil. When stoves were used, plants close to stoves were damaged and the smoke emission tubes passing though the cover materials burned and melted the cover materials (Onder, 1998).

Greenhouse heat conservation

Heat saving depends not necessarily on the kinds of the cover material but rather leakage proof of the system (Meyer and Muller, 1983). Heat curtains were used in 87.63% of the greenhouses not only during nights but they were kept closed day time as well during cold winter season. If the heat curtains were opened during day time and closed during nights, heat loss was prevented while the decrease of lighting was at the least (Emekli et al., 2007).

As for the materials used for heat curtains, 5.88, 16.47, 17.65 and 60% of the greenhouses had respectively PE, UV added PE, IR added PE and UV plus IR added PE. It was noted however that the heat curtains not only caused extra load on greenhouses structure, condensates of humidity and water drops on the curtains triggered spread of fungal diseases.

Shading and cooling of the greenhouses

There was no need of cooling in the surveyed greenhouses because production was largely made during spring and fall seasons and the greenhouses had no crops during summer. Some of the growers (72.16%) make shading of the greenhouses toward the end of spring. Small number of the growers (3.09%) uses sprinkler system for cooling if needed.

Positioning of greenhouses

The surveyed greenhouses were also examined for the direction and positioning of their construction. 77.32% of the existing greenhouses were constructed in east-west direction, and all the others were in north-south direction. Mastalerz (1977) reported that solar radiation intercepted by the greenhouses with their long sides laid in east-west direction was more uniform compared to the ones laid in north-south direction. He further noted that the greenhouses in east-west direction received 3% less solar radiation in summer; whereas, they got 48% more sun shine compared to those in north-south direction. Papadakis et al. (1998) recommended that the greenhouses at around 37°58´ N latitudes must be constructed in east-west direction for better lightening. However, if the greenhouses in Samandag region are constructed in east-west direction, parallel to cost line, the plastic cover materials does not last long and they are easily fractured due to the high winds of northeast to southeast directions. The growers in Samandag region prefer direction of their greenhouses fitting to topographic characteristics rather than wind and direction sun shine. However a demonstration greenhouse constructed by Bozkurt et al. (2006), close to cost line, did not have the mentioned wind and lightening problems. They recommended that the greenhouses of the region, close to coastal line, must ideally be directed in northeast-southwest directions.

The power cuts, inadequate water and transportation were among the general problems adversely affecting greenhouses management in the area, as generally complained by the growers. The survey work showed that the greenhouses in Samandag region had long list of technical shortcomings.

As a result, the greenhouse cropping of the area had problems of low crop yields and quality. The above mentioned technical shortcomings must be overcome if the greenhouses cropping of the area are to be improved and advanced. It is important that assistance and advice from specialized institutes and experts, including university, should be south at early phase of planning greenhouse construction, greenhouse cropping and management options.

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