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Full Length Research Paper

The comparation of costs by computure aided and ınteractive greenhouse design applicatıon

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This study aimed to determine the cost of singular greenhouses in computer having ground area of 100 to 750 m^2 by entering greenhouse size. Having determined the required amount of materials and total costs, different sizes of steel construction with gable roof greenhouses arc roof and gothic roof greenhouses were compared with each other. The cost of the greenhouse to be designed was computed using the greenhouse design application employing Delphi programming language. After entering the different options with this prepared design, the user can see required results of the basic calculation in the construction greenhouse. If necessary, the user can go back and design for different choices. This study can be used for educational purposes in addition to (also) the design of the greenhouse. With this practice, numerical examples and costs related to greenhouse can be controlled. In this study, the unit cost was determined by calculating the total cost of the greenhouse that will be designed in case of cultivation of four different plants type in different greenhouse size and covered with different materials in different type greenhouses. The offered options are chosen from required economic values for appropriate plant species and comfortable mechanization inside greenhouse. In computer, two different heights of basic type rectangular greenhouses, three different widths and six different lengths options in gable roofed glass greenhouses can be selected for seedlings / saplings, vegetables and cut flowers for each plant species. Basic type rectangular greenhouses were designed with two different heights, four different widths and six different lengths options in gothic and arc roofed covered with plastic greenhouses. For banana plant in only one height option, basic type rectangular greenhouses were designed with three different widths and six different lengths options in gable roofed glass greenhouses and four different widths and six different lengths options in gothic and arc roofed covered with plastic greenhouses. Then the different options were compared with each other by calculating the cost of designed greenhouses. With this study, the manufacturer select the greenhouse type and its cost according to the product he wants to grow by entering data which chosen by himself and will be able to see plan, section and view of chosen in the condition greenhouse.

Key words: Greenhouses, structural properties, construction, design, cost.

INTRODUCTION

The greenhouse structures used in agriculture can be analyzed in three groups such as low plastic tunnels, high plastic tunnels and greenhouses. Low plastic tunnels can be defined as simple greenhouse production areas covered with plastic material of 60 to 200 cm in width, 30 to 200 cm in height and 20 to 50 m in length with half-circle skeleton. High plastic tunnels are structures between greenhouses and low tunnels, 300 to 400 cm in width, 150 to 200 cm in height and 50 to 60 m in length with half-circle skeleton. On the other hand greenhouses are structures that provide more favorable conditions for cultivated plants and provide a higher income (TSE 1996, Ertekin 1991).

Greenhouses are structures with glass of plastic materials transmitting the light for cultivating various

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plants, their seeds, seedlings and saplings all the year round by controlling factors like temperature, moisture and ventilation if necessary without being – either entirely or relatively – dependent upon the climate changes. Greenhouses should be large enough to move in easily and enabling an environment having necessary facilities for the growth all through the year (TSE, 1996; Ustun and Baytorun, 2003).

Commercial cultivation in greenhouses, enabling productive power as well as evaluating small areas marginally by making them grow more and more productive, constitutes one of the important agricultural activities (Kendirli, 2002).

The most common greenhouse production is done in Akdeniz, Marmara and Ege regions in Turkey (Olgun et al., 1997). Antalya has the largest share in Akdeniz region and Turkey according to the amount and proportion in greenhouse production. The total covered area of about 47 thousand hectares of Turkey exists in Antalya with the amount of about 16.4 thousand hectares in 2005 (Canakci, 2005). The vegetables (98%), banana and ornamental plants (2%) are grown in greenhouses (Anonymous, 2004). Antalya also covers about 1/5 of the fruit and vegetable export amounts. There are 35 hectares modern high technology greenhouses in Antalya (Anonymous, 2009).

Greenhouses are generally built without taking the environmental factors into consideration and without calculating static and strength computations. Accordingly, either too many or too few construction materials are used. When too many construction materials are used, there is overshadowing; and in the event of using too few construction materials, destructions are likely to happen in bad weather conditions (Ustun and Baytorun, 2003).

In this study, cost analysis were done for four different plant types, different greenhouse dimensions, three different roof types and two different cover materials by using computure aided design application. So, it is possible to know about the costs, material types and amounts for given conditions before building green-houses easily.

MATERIALS AND METHODS

In rectangle base type, 40×40×60 cm in sizes with 300-dose cement was selected. In addition flooding wall made of cement of 300 dosage is calculated as 30 cm wide and 40 cm high, 20 cm of which is to be underground – so as to prevent flooding when it rains heavily. On the grounds of the fact that constructing too high flooding walls will lead to overshadowing in the greenhouses, thus they should be 0.15 to 0.30 m high and 0.2 to 0.3 m wide (Hakgoren and Kurklu, 2007; Yuksel, 2004; Cartoglu, 1990; Ones, 1986; Alkan, 1977).

Commonly-used roof types were chosen for greenhouses such as gable roofs for glass greenhouses and arc and gothic roofs for plastic greenhouses (Yuksel, 2004; Filiz, 2001; Gunay, 1980).

Standard steel profiles were used in the construction of the columns and the roof as the structure material of the frame of a greenhouse. In the glass greenhouses with gable roofs, I_{100} profile in the columns and purlins, T_{60} profile in the rafters and $L_{50,50,5}$ profile in other elements were used. In the plastic ones with arc and gothic styles, on the other hand, 3 inch profile pipes in the columns, 2 inch profile pipes in the frame of the roof and 1 inch profile pipe in the other elements made of steel are used (Hakgoren and Kurklu, 2007; Emekli and Buyuktas, 2007; Filiz, 2001; Ones, 1986; Alkan, 1977).

The columns are planned to be installed one in 3 m in the glass greenhouses with gable roofs and one in 2 m in the plastic ones with arc and gothic roofs to prevent the wind effect. In order to prevent overshadowing in both type greenhouses, rafters are planned to be installed one in every 100 cm (Emekli and Buyuktas, 2007; Yuksel, 2004; Filiz, 2001; Gunay, 1980).

Glass and plastic cover types, affected little by chemical substances and environmental factors, are chosen, and they allow light transmission well into the greenhouse. These cover types are also commonly used in agriculture (von Elsner et al., 2000; Giacomelli, 1999; Baytorun, 1995; Gunay, 1985).

The glass used in gable roofs is usually 3 and 4 mm in thickness in each sides and roof, respectively. The dimensions of the glass that will be used are recomended as 1.00 × 1.65 m (Hakgoren and Kurklu, 2007; Yuksel, 2004; Baytorun, 1995).

In the construction of arc roof and gothic plastic greenhouses, UV+IR+AF additives were used to ensure high durability and longer life. Polyethylene covers containing UV+IR+AF+AV additives prevent the drop on the plant, because moisture condensation at the inner surface of the cover material and also keep the greenhouse warm enough especially after midnight when the weather is cool. Thanks to these materials, moisture comes down not on the plants but on the margins (Emekli et al., 2007; Geoola et al., 2004; Tuzel et al., 2004; Baytorun et al., 1994).

The sizes of the grenhouses that will be built were chosen as small and medium length. Floor areas are planned between 100 and 750 m^2 for small and medium length greenhouses. Greenhouses, smaller than 100 m^2 are called small, the ones between 100 and 1000 m^2 area are called medium and the ones over 1000 m^2 are called large greenhouses. The base area should at least be 500 m^2 for a productive manner. According to the researches, average area of a greenhouse is 780 m^2 in Turkey. While the base area is 700 m^2 for glass greenhouses, it is 800 m^2 for plastic greenhouses (Yuksel, 2004; Filiz, 2001; Ones, 1986).

Three different width, namely 6, 9 and 12 m, is chosen in the glass greenhouses with gable roofs. Four different width such as 6, 8, 10 and 12 m is chosen in the plastic greenhouses with arc roofs and gothic styles. When it comes to the length of the greenhouse, 6 different length, that is 24, 30, 36, 48, 51 and 60 m was choosen. Thus, grower will be able to build a greenhouse according to the length of their own land, the smallest of which can be 6 ×24 m (144 m^2) and the largest of which can be 12 x 60 m (720 m^2). In single greenhouses, the width should be 3 m and its multiples such as 3, 6, 9, 12, 15 m etc. and the length should be between 30 and 60 m (50 m average). So the reasonable floor area should be between 9 to 12 m by 50 to 60 m. The width of optirnum roofs to be built in the greenhouses is recommended to be 9 to 12 m in the glass and 6 to 9 m in the plastic greenhouses (Yuksel, 2004; Filiz, 2001).

The height should at least be 2 m for vegetable growing greenhouses. If mechanization is thought for cultivation in the greenhouses, the height of a greenhouse should be between 2 to 3.5 m and the roof slope should be 26 to 27º in average. The roof slope is between 26 to 32º in the greenhouses in Turkey increases the fertility and quality of the plants by enabling maximum advantages of sunshines and reducing the heat loss besides contributing to decreasing the expenses arising out of the establishment (Hakgoren and Kurklu, 2007; Demir et al., 1997; Colak and Sahin, 1995).

While determining the height of a greenhouse and its roof slopes, the aforemention information is referred. So as to enable an efficient mechanization, 3 different heights such as 3, 4 and 5 m are

Table 1. The plant species that will be grown and the size of the greenhouse elements for gable- roofed glass greenhouse.

Greenhouse type	Gable-roofed glass greenhouse											
	Base type and sizes (cm)	Height of side wall (m)		Width (m)			Length (m)					
Plant type	Rectangle	h_1	h_2	W_1	W_2	W_3	L_1	L_2	L_3	L_4	L_5	L_6
Vegetable	40×40×60	3	4	6	9	12	24	30	36	48	51	60
Seed/sap	40×40×60	3	4	6	9	12	24	30	36	48	51	60
Cut flower	40×40×60	3	4	6	9	12	24	30	36	48	51	60
Banana	40×40×60	5	5	6	9	12	24	30	36	48	51	60

Table 2. The plant species that will be grown and the size of the greenhouse elements for arc-roofed and gothic-roofed plastic greenhouse.

Greenhouse type	Arc-roofed/Gothic-roofed plastic greenhouse												
	Base type and sizes (cm)	Height of side wall (m)		Width (m)				Length (m)					
Plant type	Rectangle	h_1	h_2	W_1	W_2	W_3	W_4	L_1	L_2	**L_3**	L_4	L_5	L_6
Vegetable	40x40x60	3	4	6	8	10	12	24	30	36	48	51	60
Seed/sap	40x40x60	3	4	6	8	10	12	24	30	36	48	51	60
Cut flower	40x40x60	3	4	6	8	10	12	24	30	36	48	51	60
Banana	40x40x60	5	5	6	8	10	12	24	30	36	48	51	60

chosen. While deciding on the ridge of the roof, the roof slope is chosen as 26º in the glass greenhouses with gable roofs and 1, 1.5 and 2 m is chosen in the plastic ones with arc and gothic styles.

Natural ventilation method is chosen and the ratio of total window area to total floor area is 25%. This rate was reported between 18 and 25% (Zabeltitz, 1990), 30% (Hakgoren and Kurklu, 2007) and 33% (Ozmerzi and Kurklu, 1989).

Heating systems generally used in greenhouses are stoves, central heating, fans, geothermal energy and waste energy. Central heating systems, which heat up a greenhouse by means of fluid flowing in an enclosed system, are expensive systems to install. Such a system is not recommended to be installed into a greenhouse which is under 0.25 ha. It is stated that in the event of choosing stoves to heat up a greenhouse, a stove is needed in each 50 to 60 m^2 floor area in mediterenean regions of Turkey and this should be 30 to 40 m^2 as one goes up to the north of the country (Yuksel, 2004).

In this study, stoves are chosen for heating greenhouses for all sizes. One stove is planned for each 50 m^2 floor area.

The irrigation systems used in greenhouses are mostly furrow, basin, drip or sprinkle. Furrow and basin irrigation results in evaporation on surfaces besides causing too much water to be used. In addition, these methods may lead to certain diseases. Hence, these two irrigation sytstems are not recommended for greenhouses (Onder, 1997).

Despite being expensive at the initial investment expenses, drip irrigation system is chosen because of its high productivity and economy. Due to the fact that the cost of drip irrigation system depends upon the quality of the water resource as well as its distance to the greenhouse and whether there will be pumps and filters or not. However, while accounting total cost price of a greenhouse, it is determined as roughly 100 to 150 US dollars per hectare.

In this study, the dimensions of greenhouses that will be designed in three different roof types were summerized in Tables 1 and 2 for four different plant types.

Calculating methods are prepared using Delphi programme, which realized the design of the greenhouse mentioned above. It is explained in Buyuktas et al. (2010), in detail. Application is projected to have an interface, which is interactive, user-friendly and simple. The designer of the greenhouse realizes each process by choosing the alternatives on the screen in each step.

In the first step of the application, the type of the plant (seed/sapling, vegetable, cut flower, banana) and then the height of side wall of the greenhouse (H) was chosen. The height was taken as 3 and 4 m except banana and it is just 5 m for banana cultivation. In the third step, glass or plastic cover material type and in the fourth step of the design, the measurements of the floor area of the greenhouse was chosen. The width and length dimensions for the glass and plastic covered greenhouses is shown in Tables 1 to 3. In the fifth step, roof type was chosen according to the covering type. If the covering type is glass, gable roof, if it is plastic, arc and gothic style are recommended. In the sixth step, base type was chosen. The dimensions of rectangle type respectively the length (t_a) is 0.4 m, the width (t_b)is 0.4 m, and the height (t_h) is 0.6 m as constant was taken for all design.

After all the required selections by following these steps, the unit cost was determined by calculating the total cost and the amount of material for the greenhouse that will be designed in case of cultivation of four different plants type and covered with different materials.

RESULTS

The unit cost is shown in Figure 1 for different width and length values in the gable-roofed glass greenhouses with the side wall height of 3 and 4 m. The unit cost of the greenhouse is decreased with the increase of greenhouse length and width for the gable-roofed glass greenhouses. So, increasing the ground area decreased the unit cost of the greenhouse. While the highest unit cost value with the dimension of 6 m in width and 24 m in length was 83.3 US$, the lowest unit cost value with the

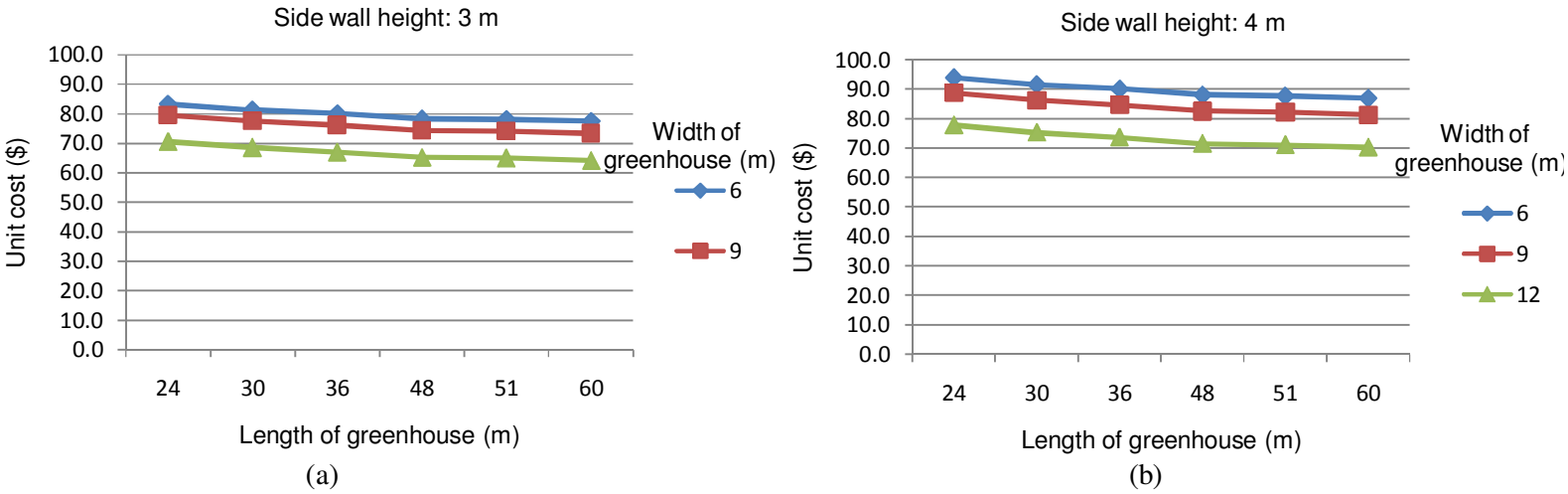

Figure 1. The unit cost in the gable-roofed glass greenhouses with the side wall height of 3 m (a) and 4 m (b).

dimension of 12 m in width and 60 m in length was 64.2 US$ for the side wall height of 3 m. As for side wall height of 4 m, the highest unit cost value is obtained with the dimension of 6 m in width and 24 m in length as 93.9 US$ and the lowest with the dimension of 12 m in width and 60 m in length as 70.3 US$. Although the length of the greenhouse increased the unit cost for up to 48 m in length, there were no significant differences on unit cost after 48 m in length. So, greenhouse length should be suggested as 48 m to achieve low unit cost.

The unit cost is shown in Figure 2 for different width and length values in the arc-roofed plastic greenhouses with the side wall height of 3 and 4 m. As shown in Figure 2, the unit cost of the greenhouse is decreased with the increase of greenhouse length and width for the side wall height of 3 and 4 m in the arc-roofed plastic greenhouses. While the highest unit cost value is reached in dimension of 8 m in width and 24 m in length as 38.8US$, the lowest unit cost value is obtained in dimension of 12 m in width and 6 0m in length as 28.4US$ for the side wall height of 3 m. The highest unit cost value was 43.9US$ for the dimension of 8 m in width and 24 m in length greenhouse and the lowest unit cost was 31.6 US$ for the dimension of 12 m in width and 60 m in length greenhouse for the side wall height of 4 m.

The unit cost is shown in Figure 3 for different width and length values of the gothic-roofed plastic greenhouses with the side wall height of 3 and 4 m. The unit cost of greenhouse is decreased in case of the increase of greenhouse length and width for the side wall height of 3 and 4 m in the gothic-roofed plastic greenhouses. The unit cost values were ranged between 29.8US4 for the dimension of 12 m in with and 60 m in length greenhouse and 39.5US$ for the dimension of 8 m in width and 24 m in length greenhouse with the side wall height of 3 m. The similar results were also obtained for the greenhouses having the side wall height of 4 m. This value is changed between 33.0US$ and 44.7US$ for the same dimensions, respectively. The unit cost is shown in Figure 4 for different width and length values in the gable-roofed, arc-roofed and gothic-roofed greenhouses with the side wall height of 5 m for banana production. The cost of greenhouse is decreased with increasing greenhouse length and width. The highest unit cost value is obtained with the dimension of 6 m in width and 24 m in length greenhouse as 104.5US$ and the lowest with the dimension of 12 m in width and 60 m in length greenhouse as 76.3US$ for the gable-roofed glass greenhouse. Although the length of the greenhouse increased the unit cost up to 48 m, it did not change significantly after the length of 48 m. These costs were changed between 34.8US$ for the dimension of 12 m in width and 60 m in length greenhouse and 49.0US$ for the dimension of 6 m in width and 24 m in length for arc-roofed greenhouses. These values were 36.2US$ and 49.8US$ for the same dimensioned gothic-roofed

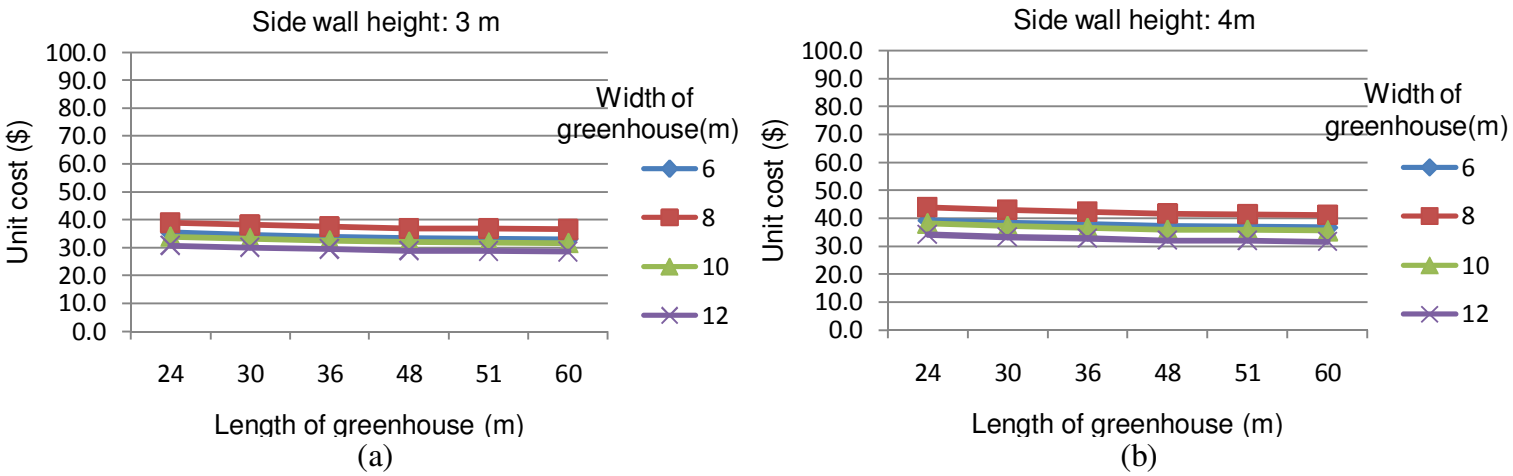

Figure 2. The uinit cost in the arc-roofed plastic greenhouses with the side wall height of 3 m (a) and 4 m (b).

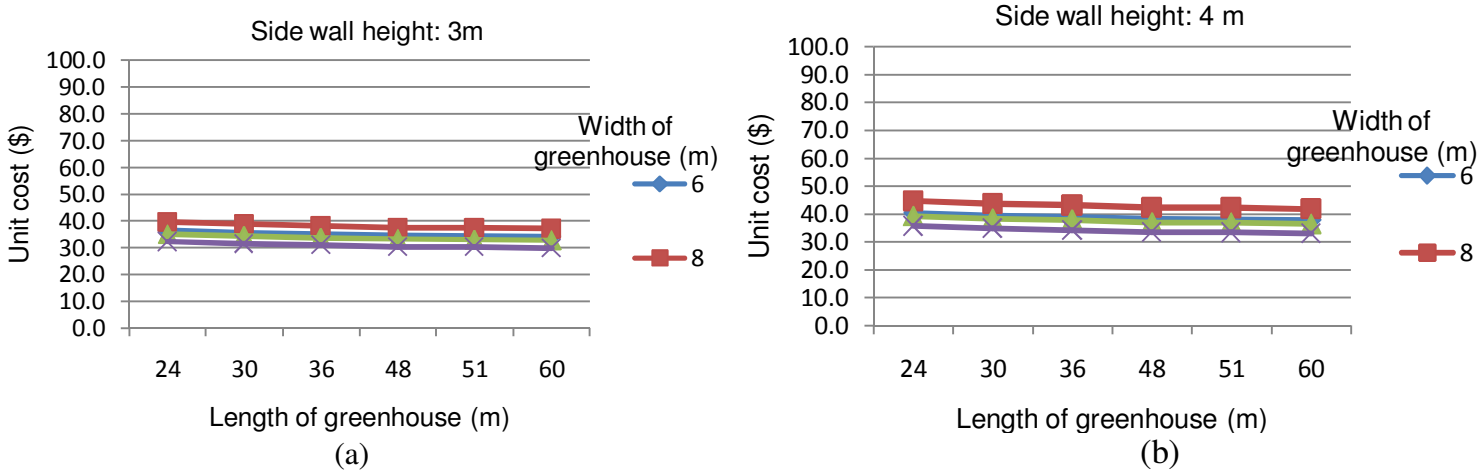

Figure 3. The unit cost in the gothic-roofed plastic greenhouses with the side wall height of 3m (a) and 4m (b).

greenhouses.

The comparisons of the unit costs of different types of greenhouses having the same side wall height, length and width were given in Figures 5 to 7. While the unit costs of the gothic and arc-roofed greenhouses were almost the same, this value was more than twice as much as in gable-roofed greenhouses. So, the gable-roofed greenhouses are more expensive than arc and gothic-roofed

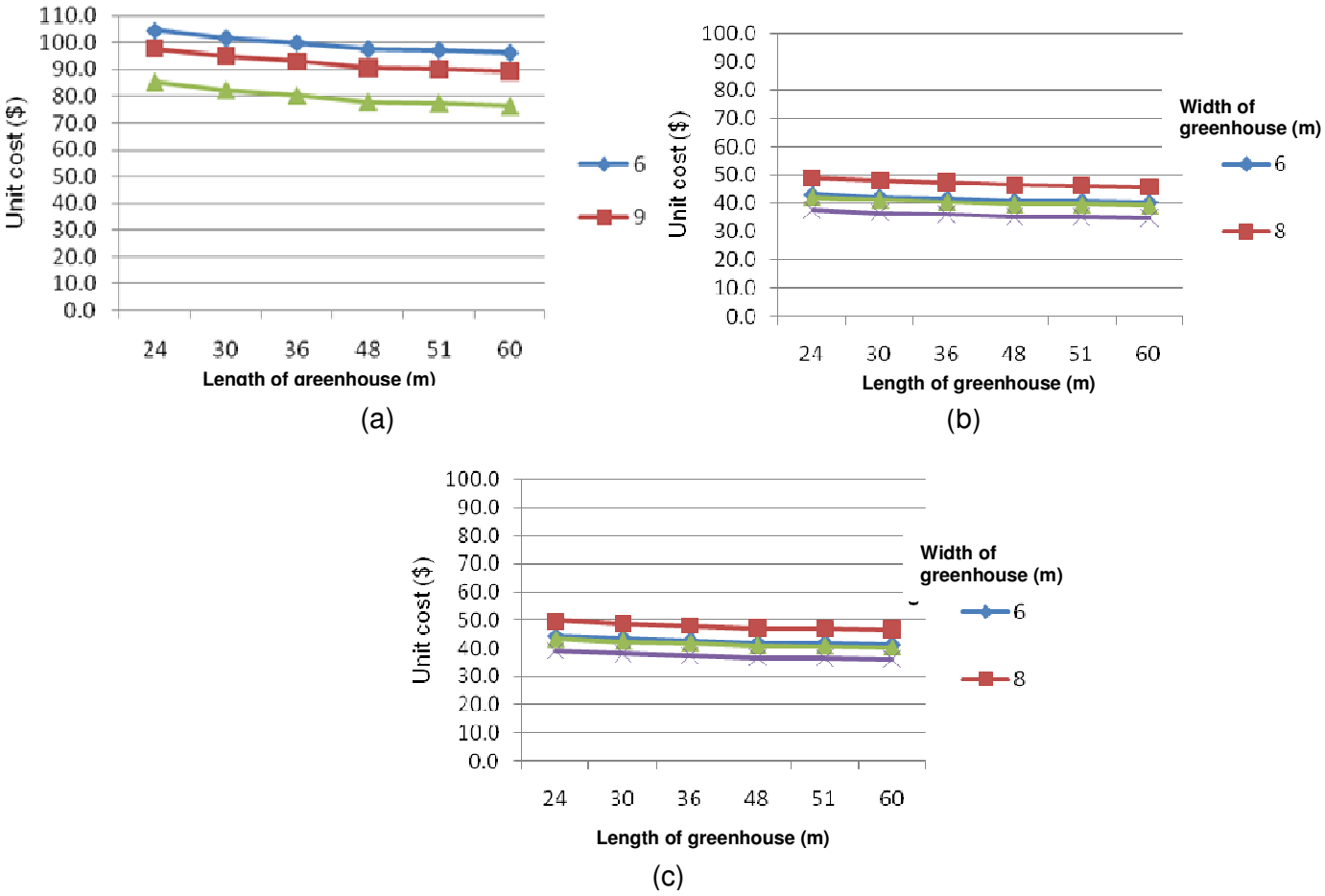

Figure 4. The unit cost in the gable-roofed (a), arc-roofed (b) and gothic-roofed (c) plastic greenhouses the side wall height of 5m for banana.

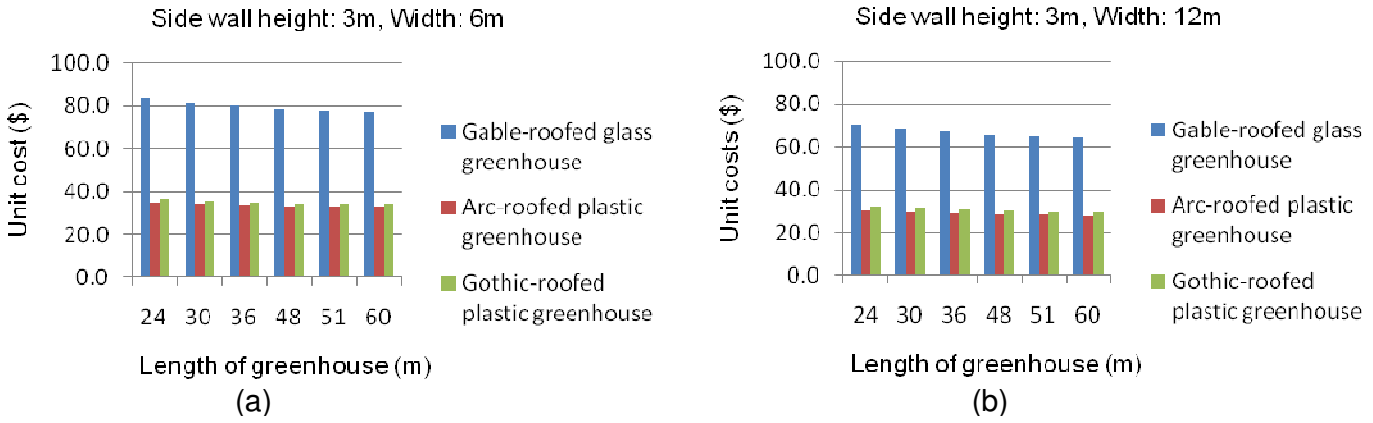

Figure 5. Comparison of the unit cost of greenhouses that designed in different roof types for 6m (a) and 12m (b) in width and the side wall height of 3m for vegatable plant.

greenhouses for unit area (Figure 5). These values were between 28.4US$ and 36.4US$ for arc and gothic-roofed greenhouses and between 64.2US$ and 83.3US$ for gable-roofed greenhouses.

As shown in Figure 6, increasing the side wall height is increased the unit costs. The unit costs were between

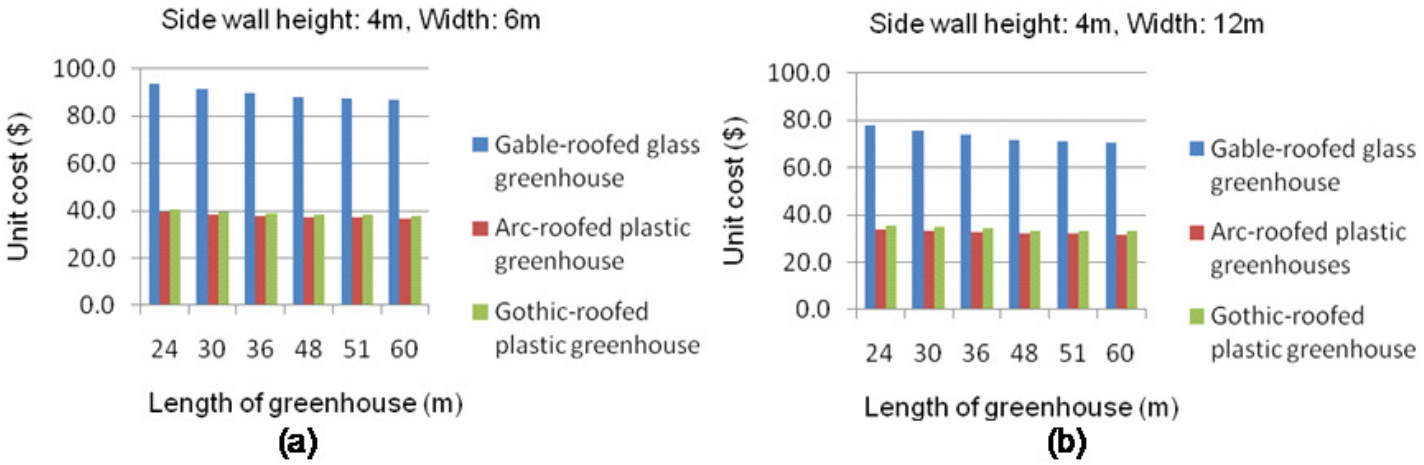

Figure 6. Comparison of the unit cost of greenhouses that designed in different roof types for 6m (a) and 12m (b) in width and the side wall height of 4m for vegatable plant.

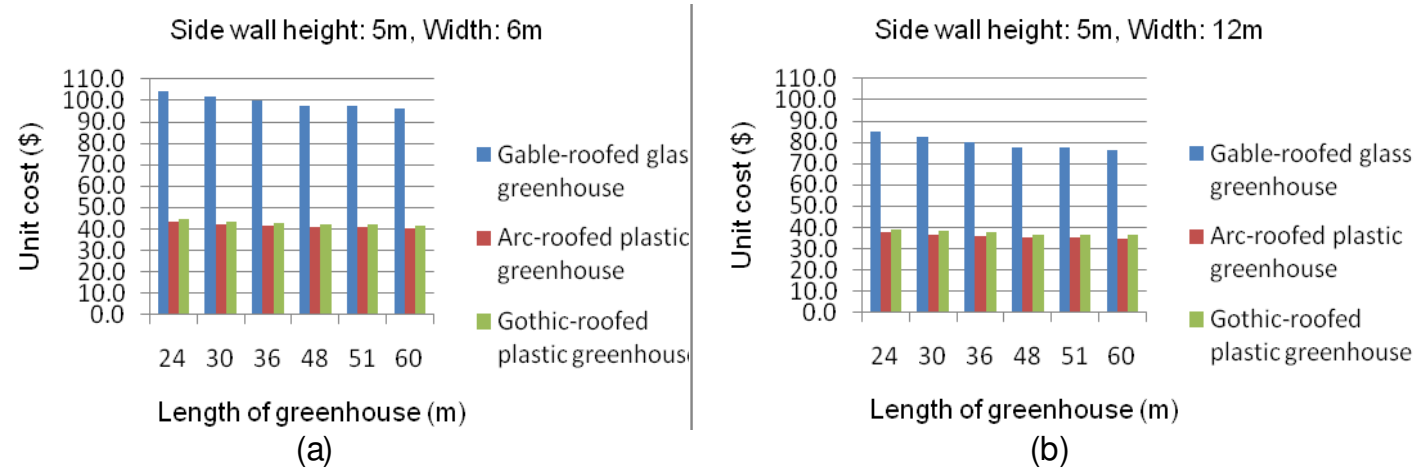

Figure 7. Comparisons of the unit cost of greenhouses that designed in different roof types for 6m (a) and 12m (b) in width and the side wall height of 5m for banana plant.

31.6US$ and 40.4US$ for arc and gothic-roofed greenhouses and between 70.3US$ and 93.9US$ for gable-roofed greenhouses.

In Figure 7, different types of greenhouses were compared for banana production. While the unit costs were similar for arc and gothic-roofed greenhouses, it was higher for gable-roofed greenhouse. These values were between 34.4US$ and 44.4US$ in arc and gothic-roofed greenhouses and between 76.3US$ and 104.4US$ gable-roofed greenhouses.

Conclusion

According to the results, the unit cost was observed more than two times in gable-roofed greenhouses than arc and gothic-roofed greenhouses in all greenhouse widths and lengths. So, in practice, the cost of a gable-roofed glass greenhouse is equal to more than two times of arc and gothic-roofed plastic greenhouses having the same size. The costs of greenhouses could be calculated easily and correctly for different alternatives. This program is useful instrument for designing a greenhouse in a shorter time with highly accurate results. The calculations of different alternatives could be made by computure media. Thus, users will calculate cost of greenhouses and can compare different alternatives to decide the final contruction. In addition, prices can easily be updated on this programme. That is, the user is able to account the costs by entering the yearly-changing prices via this programme. For this reason, this study will last long and respond to the demands of the greenhouse designers for years. It is so practical and advantegous that it can be used both in designing and in education in the fields of civil engineering and agriculture.

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