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Effect of Different Soilless Culture Systems on Productivity of Celery Crop Using Rooftops in Urban Cities

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ABSTRACT

The effect of different soilless culture systems (beds, pots and bags), modified nutrient film techniques (A-shape NFT and flat NFT) as well as foliar spray with GA_3 (0, 10, 20, 30 and 40 mg/l), were tested on the growth and yield of celery plant (*Apium graveolens* var. *dulce* cv. Royal crown).Study was done on the rooftop of the Central Laboratory for Agricultural Climate (CLAC) at Dokki, Giza, during winter seasons of 2015 and 2016. Plant height, number of leaves, chlorophyll reading, fresh and dry weight/plant, yield per m^2, as well as NPK content in shoot of celery plant were determined. Results indicated that using substrate culture systems, during the two seasons, gave the highest significant values for plant height, number of leaves, fresh and dry weight per plant, nitrogen, phosphorus and potassium content as compared with modified nutrient film techniques. The highest values of chlorophyll reading were recorded using pots and A-shape NFT systems with no significant differences between them, and with significant different with other soilless culture systems. Results also indicated that increasing the concentrations of GA_3 up to 40 mg/l led to increase in plant height, fresh and dry weight per plant, nitrogen, phosphorus and potassium contents in comparison with control treatment (spray with distilled water). On the contrary, number of leaves and chlorophyll readings did not respond to increase of foliar spry of GA_3 concentrations as compared with control treatment. The highest total yield (Kg/m^2) was recorded using bed system flowed by A-shape NFT system without a significant difference between them. Bed system gave the highest significant values of fresh weight per plant with the lowest number of plants per m^2 (16 plant per m^2), while A-shape NFT system gave the lowest values of fresh weight per plant with a greater number of plants per m^2 (24 plant per m^2) as compared with the others soilless culture systems.

As for the interaction effect between soilless culture systems and foliar spray of GA_3, results showed that using substrate culture systems i.e. bed, pot and bag combined with 40 mg/l GA_3 gave the heights significant values of fresh and dry weight/ plant as compared with modified nutrient film technique systems (A-shape NFT or flat NFT) at the same concentration of 40 mg/ l GA_3. The highest values of fresh and dry weight/ plant were obtained with bed system at 40 mg/ l of GA_3, while the lowest values were found with flat NFT system + spray with distilled water. The highest total yield per m^2 was recorded with A-shape NFT system combined with 40 mg/l GA_3 followed by beds system combined with 40 mg/l GA_3 without significant difference between them (Note, the number of plants in both systems is different). On the other hand, the lowest yields per m^2 were recorded with flat NFT system without spray of GA_3 followed by spray 10 mg/ l GA_3.According to the Egyptian market, the celery plant is sold as a single plant not by weight, so the commercial exploitation of rooftops to produce celery crop with modified NFT systems are preferred because it has the highest number of plants per meter square and net profit is high in comparison with substrate systems. On the other hand, when the rooftops are used for the purpose of domestic use, the system of beds is preferred because the weight of single plants is high and the cost of production is low as compared with other soilless culture systems.

Key words: Soilless Culture Systems, substrate culture systems, NFT system, Rooftops, Urban Cities, Celery

Introduction

Overpopulation and climate change effects put great stresses on agricultural production in Egypt causing reduction in food security. Many urban areas in the world are trying to enhance food sustainability by improving urban farming through installing rooftop gardens for the production of

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fresh vegetable crops. Urban horticulture should play a vital role in reducing the vulnerability to climate change and producing food using green roof systems (Abul-Soud *et al*., 2014).

Soilless culture technology is defined as "any method for growing plants without the use of soil as a rooting medium, where soilless culture offers an ideal alternative crop production for traditional cultivation in soil when there is no soil available at all (Olympios, 2011).Many systems of soilless culture can be applied on rooftops gardens such as pot substrate, horizontal bag substrate bed substrate(Neveen Metwally, 2016) and modified NFT systems,such as A-shape NFT and flat NFT (Orsini, 2012).The use of soilless culture systemsfor cultivating rooftopsin urbane cities,where there is no available soil, limited spaces and adverse production conditions makes green roofs, which can contribute positively to make cities more livable (Luckett, 2009). On the other hand, green roofs application in urban area, it is possible to contribute to the mitigation of environmental problems, enhancement of community functions and development of urban food systems by providing the local vegetables and food production for people living in urbane cities (Lim and Kishnani, 2010). Many crops and vegetables, such as celery (*Apium graveolens*), can successfully produce using soilless culture systems and green rooftops in urban cities.

Soilless culture systems has been used in the cultivation of vegetables and garden plants (Singh and Singh, 2012).Celery, as leafy vegetable crop, can be produced using soilless culture systems on rooftops in urban cities. Celery is an excellent source of vitamin C, folate, B1, B2, B6, A, dietary fiber, K, Ca, Mg, P and Fe (Mitra *et al.,* 2001). Also, it is used worldwide in human nutrition. The green parts of the plant are used insoups and salads and have been found to contain biologically active compounds (Winston, 2005 and Wen *et al.,* 2006). Moreover, it has been used in traditional medicine, primarily as a diuretic and it can treat sbronchitis, asthma, liver and spleen diseases (Singh and Handa, 1995).

On the other hand, Gibberellic acid (GA_3) is a plant hormone belongs to gibberellins (Mahmoody and Noori, 2014). It is well known that vegetative growth of plantsis promoted by foliar application of gibberellin in many vegetable crops. Growth promoting hormones are commonly used in agriculture to increased productivity, where gibberllic acid is used as a growth stimulating substance for promoting cell elongation, cell division that leads to promote growth of many plant species. Increase in the length of leaf stalk and fresh weight of field grown celery plant following gibberellin application has proved to bring profit (Kato and Ito, 1962 and Guzman, 1969).

In this regard, the effect of spray of gibberellic acid (GA_3) at very low concentrations could be exploited beneficially as its natural occurrence in plants in minute quantities is known to control their development. It is an established phytohormone used commercially for improving the productivity and quality of a number of crop plants (King and Evans, 2003).

Therefore, the aim of this investigation was to study the effect of different soilless culture systems and foliar spray with gibberellic acid at different concentrations on the growth and productivity of celery crop on the roof of Central Laboratory for Agricultural Climate (CLAC) as example of green rooftops in urban cities.

Materials and Methods

The experiment was carried out on rooftop of Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Centre, Ministry of Agriculture and Land Reclamation, Egypt, during the two winter seasons of 2015 and 2016, to investigate the effect of different soilless culture systems and different concentration of gibberellic acid as foliar spray on the growth and yield of celery plants.

Celery (*Apium graveolens* var. *dulce* cv. Royal crown) seeds were sown, on the first week of September 2015 and September of 2016, in foam trays. After the fourth true leaf stage, celery seedlings were transplanted into different growing systems of soilless culture. The different soilless culture systems were: pots system, horizontal bags system and beds system as a substrate culture systems, as well as A-shape NFT and flat NFT, as a modified Nutrient Film Technique system. All systems of substrate culture were carried out in wood tables as follows: 1 m length, 1 m width, 10 cm depth and 60 cm height above the rooftop ground. The wood tables were covered with black polyethylene sheets (1mm thickness), with a drainage hole in each, to collect the leaching of nutrient solution to the main tank to offer close substrate culture.

Description of substrate culture systems

Pots system

The growing plastic pots were 7 L volume (20 cm diameter x 25 cm length) filled with 6L substrate mixtures of perlite and peat moss (1:1 *v/v*).One seedling was planted in each pot, where each wood table contains 16 pots and the distance between seedlings was 25 cm. The number of plants per square meter was 16 plants.

Horizontal bags system

Four horizontal bags, made from double face polyethylene sheets (0.2mm thickness), were placed in each wood table. The inside face of horizontal bags was black and the outside was white. Each bag, 100cm length, 25cm width and 9cm height, was filled with 20 L substrate mixtures of perlite and peat moss (1:1 *v/v*). Holes were made in the lowermost in both sides and front of each bag for drainage to release the excess nutrient solution and 4 bigger holes in the surface for 4plant seedlings, the distance between seedlings 25 cm. The number of plants per square meter was 16 plants.

Beds system

The wood tables, as previously described, were each filledwith100L of substrate mixtures of perlite and peat moss (1:1 *v/v*). Each planted with 16 seedlings and the distance between seedlings was25 cm. The number of plants per square meter was 16 plants.

Description of modified Nutrient Film Technique (NFT) system

System consists of iron frame, PVC plastic pipes with 4 inches diameter and 3 m length and a wooden tank (length 0.9 m, width 0.4 m, depth 0.5 cm) covered with black polyethylene sheet (1 mm thickness).The tank capacity about 180 L, was filled with nutrient solution with adjusted pH in the range of 6.5 to 6.8, and EC at around 2 dS/m. Nutrient solution was withdrawn from tank by submersible pump (80 watt) via irrigation pipe (16 mm), this irrigation pipe was connected to the upper end of the PVC plastic pipes. The flow of the nutrient solution used was 4 litres per hour. The nutrient solution was collected from each plastic pipes by a plastic funnel fixed in the lower end of the plastic pipe and then into the tank again as a closed irrigation system. The nutrient solution was switched-on twelve times a day for a period of 15 minutes each time. Seedlings were planted in small bags filled with 0.3 L/plant of substrate mixtures of perlite and peat moss (1:1 *v/v*).Each small bag was 8 cm length, 6 cm width and 14 cm height, which perforated from the bottom. Plants were placed at 25 cm distance between plants in the same plastic pipes in holes performed in the upper part of the plastic pipe. Two types of modified Nutrient Film Technique (NFT) were used in this study (A-shape NFT system and flat NFT system).

A-shape NFT system

The A-shape system consists of triangle iron frame with dimensioned 100 X 100 X 80 cm forming about 60 degrees triangle, then PVC plastic pipes with diameter 4 inches and 3 m length. The pipes fixed on this frames on the height of 40 cm from the rooftop surface to perform the bottom level, 25 cm from the bottom level to perform the middle level and 25 cm from the middle level to perform the top level. Plants were housed at 25 cm distance between the plants in the same plastic pipes in holes performed in the upper part of the plastic pipe. Iron frame hold six plastic pipes. The number of plants per square meter was 24 plants.

Flat NFT system

The flat NFT system consists of flat iron frame with dimensioned flat part length 100 cm and high from the rooftop surface 60 cm, PVC plastic pipes with diameter 4 inches and 3 m length, pipe fixtures on the flat part of iron frame. Plants were placed at 25 cm distance between plants in the same plastic pipes in holes performed in the upper part of the plastic pipe. Iron frame hold six plastic pipes. The number of plants per square meter was 20 plants.

Some physical and chemical properties of substrate mixture

Some physical and chemical properties of substrate mixtures of perlite and peat moss (1:1 v/v) were illustrated in Table (1). The physical properties i.e. bulk density BD (g/l), total pore space TPS (%), water hold capacity WHC (%) and air porosity AP (%) were estimated according to Wilson (1983) and Raul (1996). The pH of the potting mixtures were determined using a redistilled water suspension of each potting mixture in the ratio of 1:10 (*w: v*) that had been agitated mechanically for 2 h and filtered through filter paper number one (Inbar *et al*., 1993). The same extract was measured for electrical conductivity (EC) by EC meter.

Table 1: Physical and chemical properties of substrate mixtures of perlite: peat moss (1:1 *v/v*).

Properties	Physical				Chemical	
	BD (g/l)	TPS	WHC	AP	EC (dS/m)	pH
		%				
Value	0.14	65.20	52.80	12.50	0.45	7.60

Nutrient solution and system fertigation

Nutrient solution of El-Behairy (1994),which contains macro and micronutrients as follows: N 259.6, P 35, K 300, Ca 160.2, Mg 50, S 221, Fe 5,Mn 1, Zn 0.1, Cu 0.1, B 0.3 and Mo 0.1 as mg/l was used in this study. The substrate culture systems (pots system, horizontal bags system and beds system) were fertigated from tank filled with nutrient solution with an adjust pH in the range of 6.5 to 6.8 and EC around 2 dS/m.The tank, constructed in form (length 2 m, width 1 m, depth 30 cm), was covered with black polyethylene sheet (1 mm thickness) to present about 0.5 $m^3$of nutrient solution located on tank supported by woodden frame. The nutrient solution was pumped via submersible pump (80 watt) through drip irrigation system (4L/hr). The nutrient solution was switched on two times a day eachfor 15 minutes. Each 3 tables were served by 1 main tank. The woodden tables used to establish different systems of substrate culture (pots system, horizontal bags system and beds system) are as previously mentioned.

Treatments:

This experiment included two factors. The first factor was five soilless culture systems and the second factor included the five GA_3 concentrations. The GA_3 concentrations were added to the plants, via foliar spry, two times at 30 and 45 days after transplanting. The control treatment, via foliar spry of distilled water, was added at the same times. The different treatments of foliar spray were applied on the plants with equal even spray.

A- Soilless culture systems:
1- Pots substrate system
2- Horizontal bags substrate system
3- Beds substrate system
4- A-shape NFT system
5- Flat NFT system

B- Foliar spray of Gibberellic acid (GA_3)
1- Foliar spry of distilled water (control)

2- Foliar spray at concentration of 10 mg/ l
3- Foliar spray at concentration of 20 mg/ l
4- Foliar spray at concentration of 30 mg/ l
5- Foliar spray at concentration of 40 mg/ l

The measurements

Vegetative growth parameter and yield:

Plants were harvested after 75 days from transplanting. The plants were washed with distilled water and samples of three plants of each experimental plot (m^2) were taken to determine growth parameters as follows: plant height (cm), number of leaves, fresh weight, dry weight, chlorophyll reading (SPAD) and total yield per m^2.

Chemical analysis:

Plant content of N, P and K (%) were estimated. Three plant samples at the harvest stage of each plot (m^2) were dried at 70ºC in an air forced oven for constant weight. Dried plant samples were digested in mixture of $HClO_4$ and H_2SO_4 acids according to the method described by Allen (1974).The content of N, P and K were estimated in the acid digested solution. Total nitrogen was determined by Kjeldahl method according to the procedure described by Page *et al.,* (1982). Phosphorus content was determined by colorimetric method (ascorbic acid) using spectrophotometer according to Page *et al.,* (1982). Potassium content was determined photo-metrically using Flame photometer as described by Chapman and Pratt (1961).

The economic study

Total cost (6m^2 per system) determined by the total construction costs (calculated 20 planting times for 10 years) + total production costs (seedling + irrigation + chemicals + electricity +substrate+ others).

Total return (6m^2 per system) determined by the yield market price per plant (depending on the physical quality) ×number of plants (6m^2 per system) ×two times planting per season

The net profit (6m^2 per system) determined by the total return – total cost.

Statistical analysis

The experimental design was a spilt-plot design with 3 replicates. The Soilless culture system was assigned as main plots and gibberellic acid concentrations as subplots. Data were statistically analyzed by the analysis of variance one way ANOVA using SAS package software version 6 SAS Institute (1990). Tukey test was used to compare the significant differences among means of the treatments at 0.05 level of probability

Results and Discussion

Effect of soilless culture systems and foliar spry of GA_3 on plant height, number of leaves and chlorophyll reading of celery plant

Data in Tables (2, 3 and 4) illustrate the effect of different soilless culture systems (substrate culture systems and modified nutrient film technique) and different foliar application of gibberellic acid concentrations (0, 10, 20, 30 and 40 mg/ l) on vegetative growth parameters (plant height and number of leaves) and chlorophyll reading during the two winter seasons of 2015 and 2016.

Data in Table (2) show that, substrate culture systems, in the two seasons, gave the highest significant values of plant height and number of leaves as compared with modified nutrient film technique systems. Bed, pot and horizontal bag systems, in the two seasons, gave the highest values of plant height and number of leaves without significant difference among them. The lowest values were recorded with A-shape NFT system and flat NFT system without significant difference between them. The superiority of substrate culture systems on modified NFT systems may be due to the difference in the volume of the growth media (the volume of substrate culture systems ranged between 5 to 6.25 L/ plant, while modified nutrient film technique systems were 0.3 L / plant) as well as to the good properties of substrate mixture with substrate culture systems (good aeration and dark condition for root development) which led to the increase in growth of roots, increase in the absorption of nutrients and thus increase in vegetative growth parameters as compared with A-shape NFT and flat NFT systems. These results agreed with Dayananda and Ahundeniya (2000).They found that the vegetative growth parameters of lettuce grown on aggregate systems (six growing media) were higher than hydroponic systems (nutrient flow system and non circulating system) where the nutrient supply in the aggregate system was much better than the other two systems, and absorption of nutrients was quick, and this system had good aeration and provided dark condition for root development. On the other hand, the highest values of chlorophyll reading (SPAD) were recorded using pot and A-shape NFT systems without significant difference between them and with significant different with the other soilless culture systems. The lowest values were recorded using bed, bag and flat NFT systems without significant different among them.

Table (2) data also revealed that, increase the concentrations of gibberellic acid, up to 40 mg/ l, increased plant height in comparison with control. On the contrary, number of leaves and chlorophyll readings did not respond to increase gibberellic acid concentrations as compared with control. The highest value of leave number and chlorophyll readings were found with control treatment, while the lowest values were recorded with foliar application of gibberellic acid at40 mg/ l. These results were in agreement with Kato and Ito (1962) and Guzman (1969). They found that, response of celery and other vegetable crops to foliar spry of gibberellic acid concentrations were mostly in stem elongation, increase in yields and dry matter, advanced maturity and early flower stalk initiation. Many investigators mentioned gibberellic acid effect on plant growth, through its effect on stem elongation and cell division. Neil and Reece (2002) mentioned that gibberellic acid is one of the most active hormones of gibberellins. It affects many mechanisms of plant growth including stem elongation by stimulating cell division and elongation, flowering, fruit development and breaking dormancy. Abd El-Hameid *et al.,* (2008) mentioned that the stimulating effect of GA_3 on shoot height is due to its effect on cell elongation and cell division.

As for the interaction effect between soilless culture systems and foliar application of gibberellic acidon plant height, number of leaves of celery plantsdata in Table (2) showed that the foliar spry of gibberellic acid at 30 and 40 mg/ l combined with all soilless culture systems gave the highest significant values of plant height as compared with control treatment and without significant difference between them. This was true during the two seasons of study. On the contrary, the number of leaves and chlorophyll reading did not respond to the increases in foliar spray of gibberellic acid concentrations under all soilless culture systems. Increasing concentration of gibberellic acid with all soilless culture systems led to decrease the number of leaves as compared with control treatment. The highest values of the number of leaves during the two seasons found with control treatment compared to all soilless culture systems, without significant difference among them. While the lowest values were found with 40 mg/l gibberellic acid in all soilless culture systems, without significant difference among them. Concerning chlorophyll reading, also increasing concentration of gibberellic acid with all soilless culture systems led to the decrease in chlorophyll readings as compared with control treatment. The highest value of chlorophyll reading was resulted from A-shape NFT system with foliar spray of distilled water (control treatment), while lowest value was recorded using beds system with foliar spray of gibberellic acid at 40 mg/l. This trend was true during the two seasons of study except with pots system during the second season with non spray with GA_3 (foliar spray with distilled water), which exhibited no significant difference with A-shape NFT system with non spray with GA_3 (control treatment).

Table 2: Effect of different soilless culture systems and different foliar spray of GA_3 concentrations (mg/ l) on plant height, number of leaves and chlorophyll reading of celery plants.

Treatments	First season			Second season		
	Plant height (cm)	No. of leaves	Chlorophyll reading (SPAD)	Plant height (cm)	No. of leaves	Chlorophyll reading (SPAD)
Soilless culture systems						
Beds	72.9 AB	19.9 A	34.2 C	75.5 A	23.3 A	32.4 B
Pots	72.5 AB	19.7 A	35.8 AB	74.4 AB	23.2 A	34.2 A
Bags	73.4 A	19.1 A	34.6 BC	75.1 A	22.3 AB	32.8 B
Flat NFT	71.3 BC	17.7 B	34.3 C	73.1 BC	20.5 BC	32.7 B
A-shape NFT	70.8 C	17.9 B	36.8 A	72.6 C	21.3 C	35.0 A
Gibberellic acid concentration						
Control	60.7 D	22.1 A	39.1 A	62.3 D	25.8 A	38.0 A
10	69.3 C	20.1 B	35.7 B	69.3 C	23.6 B	33.8 B
20	74.8 B	18.0 C	34.5 C	76.1 B	20.9 C	32.8 CB
30	77.9 A	17.2 C	33.7 CD	81.3 A	20.2 C	32.0 C
40	78.2 A	17.1 C	32.7 D	81.7 A	20.1 C	30.5 D

Table 2: Cont.

Treatments		First season			Second season		
		Plant height (cm)	No. of leaves	Chlorophyll Reading (SPAD)	Plant height (cm)	No. of leaves	Chlorophyll reading (SPAD)
Soilless culture systems* Gibberellic acid concentration							
Beds	Control	60.3 e	22.7 a	37.8 b	61.7 f	26.7 a	35.8 bc
	10	71.7 c	23.0 a	34.8 bc	70.3 e	26.7 a	32.9 d
	20	74.3 bc	19.3 bc	34.1 cd	79.3 b	21.7 bc	32.4 de
	30	79.0 ab	17.7 bc	33.8 cd	82.7 ab	21.0 c	31.9 de
	40	79.0 ab	17.0 c	30.6 d	83.3 a	20.7 c	28.9 e
Pots	Control	63.7 de	23.0 a	38.3 ab	64.7 f	26.0 ab	40.5 a
	10	71.3 c	22.3 a	37.1 bc	71.3 e	26.3 ab	33.8 bc
	20	73.3 bc	19.3 bc	34.4 c	75.7 d	22.3 bc	32.5 d
	30	76.7 ab	16.7 c	34.8 c	80.0 ab	20.7 c	32.9 d
	40	77.3 ab	17.3 c	34.2 cd	80.3 ab	20.7 c	31.2 de
Bags	Control	63.7 de	21.0 ab	37.9 b	64.0 f	25.0 ab	35.8 bc
	10	71.3 c	19.7 b	35.5 bc	72.3 de	24.0 b	33.6 c
	20	75.8 b	18.3 bc	35.5 bc	74.7 de	21.7 bc	33.5 cd
	30	78.8 ab	18.3 bc	32.3 cd	82.7 ab	20.3 c	31.1 de
	40	77.2 ab	18.3 bc	31.6 d	81.7 ab	20.3 c	29.9 e
Flat NFT	Control	57.3 e	22.0 a	37.3 bc	60.7 f	25.3 ab	36.2 b
	10	68.0 cd	17.3 c	35.3 bc	69.0 e	19.3 c	33.4 cd
	20	76.3 b	16.7 c	33.0 cd	74.7 de	19.3 c	32.2 de
	30	78.0 ab	16.7 c	32.8 cd	80.0 ab	19.7 c	31.0 de
	40	77.0 ab	16.0 c	32.9 cd	81.3 ab	19.0 c	30.5 de
A-shape NFT	Control	58.3 e	21.7ab	44.0 a	60.7 f	26.0 ab	41.5 a
	10	64.3 d	18.0 bc	35.8 bc	63.3 f	21.7 bc	35.1 bc
	20	74.0 bc	16.3 c	35.5 bc	76.0 bd	19.7 c	33.5 cd
	30	77.0 ab	16.7 c	34.8 c	81.0 ab	19.3 c	32.9 d
	40	80.3 a	16.7 c	34.0 cd	82.0 ab	19.7 c	32.1 de

Effect of soilless culture systems, and foliar spry of GA_3 on fresh weight, dry weight and total yield per m^2 of celery plant.

Data in Table (3) show the effect of soilless culture systems and different foliar concentrations of GA_3 on fresh weight/plant, dry weight/plant and total yield/m^2 of celery plants grown on rooftops. Data indicated that, all substrate culture systems increased fresh weight and dry weight per plant as compared with modified nutrient film technique systems. The highest significant values of fresh and dry weight per plant, during the two seasons, was found using beds system followed by the other substrate culture systems (pots and bags systems) with no significant differences between them. The lowest values was found with A-shape NFT and flat NFT systems with no significant differences between them. These results may be due to the differences in container size, which affects the volume of substrate available for root growth. Varying container sizes alter the rooting volume of the plants, which greatly affect plant growth. In this concern, the volume of the growth media differed as follows: beds 6.25 L/ plant, pots 6 L/ plant, horizontal bags 5 L/plant, flat NFT 0.3 L/ plant and A-shape NFT 0.3 L/ plant. Therefore, the beds system offered biggest substrate volume per plant, and this gave plants the opportunity to build a good root system, which led to increase the absorption of nutrients allowing plants to grow more than other substrate culture systems. On the other hand, because of the nature of the root systems of celery plant (shallow root), the beds system present a suitable substrate area (1 m^2) and depth (10cm) for plants to make a strong root system which leads to the increase in nutrients absorption plant growth more than other substrate systems followed by the increase in fresh weight and dry weight per plant. These results were in agreement with those of many studies. Kemble *et al*., (1994) and Oagile *et al.,*(2016) reported that bigger container size enhanced tomato seedlings growth and development, with respect to plant height, leaf number and area, and shoot fresh and dry weights, when compared to smaller containers. This signifies that for quality seedlings, bigger containers are the most desirable. Furthermore, NeSmithand Duval (1998) mentioned that plants undergo many physiological and morphological changes in response to reduced rooting volume, which affects transplant quality and performance, where root and shoot growth, biomass accumulation and partitioning, photosynthesis, leaf chlorophyll content, plant water relations, nutrient uptake, respiration, flowering, and yield all are affected by root restriction and container size. Also, Neveen Metwally (2016) mentioned that increased containers size from 2.5 liters to 5 liters increased plant height, number of leaves and aerial parts fresh and dry weights of hot pepper plants.

Concerning the effect of different soilless culture systems on total yield per m^2, data in Table (3) show that the highest total yield (Kg/ m^2) were recorded using bed system flowed by A-shape NFT system, without significant difference between them. This result may be due to that bed system gave the highest significant values of fresh weight per plant (16 plant per m^2) while A-shape NFT system gave the lowest values of fresh weight per plant and had a greater number of plants per m^2 (24 plant per m^2), compared with the others soilless culture systems. The number of plants in all substrate systems was 16 plants per m^2,while flat NFT system was 20 plants per m^2.This result was in agreement with Maboko and Plooy (2009).They studied five densities of four lettuce cultivars per m^2 (50, 40, 30, 25 and 20 plants per m^2) in a soilless production system and found that the increase in plant density per m^2 lead to significant increase in yields of leafy lettuce, and the higher values of yield per m^2 was at the closest spacing (50 plants per m^2).Similar results were found with the same plants as mentioned by Badi *et al*. (2004).

Regard to the effect of different concentrations of gibberellic acid, as foliar spry, on the yield of celery plants, data in Table (3) revealed that, increasing concentrations of gibberellic acid up to 40 mg/ l significantly increased fresh weight per plant, dry weight per plant and total yield per m^2 as compared with control treatment. Differences among all treatments of gibberellic acid were significant. These results may be due to the effect of gibberellic acid on cells division, accelerate plant growth (leaves and stem) and increase nutrient uptake. Consequently, fresh and dry weight per plant and yield per square meter of celery plants were increased. These results were in agreement with El-Naggar *et al.,* (2009).They concluded that there is evidence that leaves and fresh and dry weight of *Dianthus caryophyllus* L. increased as a result of foliar spry of gibberellic acid by accumulation of some biomolecules mainly responsible for cell division and subsequent enlargement and this leads to the thickened and larger leaves. Same results were obtained by Currah and Thomas (1979), on carrot plant, Abdel-Rahim and Abdel-Aziz (1983) on lettuce plant, Olympios (1976) on eggplant, Mukhtar (2004) on cowpea and El-Zohiri (2015) on globe artichoke plant.

Table 3: Effect of different soilless culture systems and different foliar spray of GA_3 concentrations (mg/ l) on fresh and dry weight (g/ plant) and total yield (kg/ m^2) of celery plants.

Treatments	First season			Second season		
	Plant fresh weight(g)	Plant dry weight(g)	Total yield (Kg/ m^2)	Plant fresh weight(g)	Plant dry weight(g)	Total yield (Kg/ m^2)
Soilless culture systems						
Beds	919.1 A	53.1 A	14.7 A	965.9 A	56.5 A	15.5 A
Pots	867.0 B	50.5 B	13.9 B	924.1 B	54.5 B	14.8 B
Bags	860.7 B	50.2 B	13.8 B	927.3 B	54.4 B	14.8 B
Flat NFT	627.5 C	40.5 C	12.5 C	655.5 C	43.3 C	13.1 C
A-shape NFT	608.3 C	40.2 C	14.6 A	640.2C	42.4 C	15.4 A
Gibberellic acid concentration						
control	675.4 E	41.5 D	12.1 E	707.4 E	43.6 D	12.7 E
10	739.2 D	45.3 C	13.0 D	772.4 D	47.9 C	13.7 D
20	774.9 C	47.2 B	13.9 C	820.4 C	51.1 B	14.7 C
30	808.7 B	47.9 B	14.5 B	862.7 B	51.9 B	15.5 B
40	884.4 A	52.6 A	15.9 A	950.1 A	56.5 A	17.1 A

Table 3: Cont.

Treatments		First season			Second season		
		Plant fresh weight(g)	Plant dry weight (g)	Yield per m^2(Kg)	Plant fresh weight(g)	Plant dry weight (g)	Yield per m^2(Kg)
Soilless culture systems * Gibberellic acid concentration							
Beds	Control	774.7 e	46.3 d	12.4 f	803.3 f	46.7 de	12.9 gh
	10	947.3 b	53.7 bc	15.2 c	978.0 c	55.3 c	15.6 cd
	20	937.7 bc	52.3 c	15.0 c	981.7 c	58.7 b	15.7 cd
	30	941.3 bc	53.7 bc	15.1 c	979.3 c	57.3 bc	15.7 cd
	40	994.3 a	59.7 a	15.9 ab	1087.3 a	64.3 a	17.4 ab
Pots	Control	755.7 e	43.3 e	12.1 f	819.7 f	47.7 de	13.1 g
	10	823.0 d	49.7 c	13.2 e	860.0 e	52.3 cd	13.8 f
	20	882.7 cd	50.0 c	14.1 de	931.0 d	54.7 c	14.9 de
	30	886.7 c	50.3 c	14.2d	959.7 cd	55.0 c	15.4 d
	40	987.0 ab	59.3 a	15.8 bc	1050.0 b	62.7 ab	16.8 bc
Bags	Control	758.7e	44.7 de	12.1 f	800.7 f	46.3 e	12.8 gh
	10	841.3 cd	50.0 c	13.5 de	918.7 d	54.0 c	14.7 e
	20	841.0 d	49.7 c	13.5 e	908.3 d	54.0 c	14.5 e
	30	903.7 de	51.3 c	14.5 cd	980.3 c	57.7 bc	15.7 cd
	40	959.0 ab	55.3 b	15.3 bc	1028.3 b	60.0 b	16.5 bc
Flat NFT	Control	525.0 h	34.7 g	10.5 g	547.7 j	36.0 g	11.0 i
	10	546.3 h	37.0 fg	10.9 g	551.0 j	37.3 g	11.0 i
	20	595.0 gh	42.0 e	11.9 f	616.7 i	44.0 ef	12.3 h
	30	694.7 f	42.0 e	13.9 de	719.7 g	45.0 e	14.4 ef
	40	776.3 e	46.7 d	15.5 bc	842.3 ef	49.7 d	16.8 b
A-shape NFT	Control	563.0 h	38.7 f	13.5 de	565.7 j	41.3 f	13.6 fg
	10	538.0 h	36.3 fg	12.9 ef	554.3 j	40.7 f	13.3 fg
	20	618.0 g	42.0 e	14.8 cd	664.3 h	44.3 ef	15.9 cd
	30	617.0 g	42.0 e	14.8 cd	674.3 h	44.3 ef	16.2 c
	40	705.5 f	42.0 e	16.9 a	742.3 g	46.0 e	17.8 a

As for the interaction effect between soilless culture systems and foliar spray of gibberellic acid on fresh and dry weight/ plant and total yield /m^2 of celery plant, data in Table (3) show that, during the two seasons, using any one of substrate culture systems (beds followed by pots followed by bags systems) combined with 40 mg/ l gibberellic acid gave the heights significant values of fresh and dry weight/ plant as compared with modified nutrient film technique systems (A-shape NFT or flat NFT system) at the same concentration of 40 mg/l gibberellic acid. The highest values of fresh and dry weight/ plant were found with bed system at 40-mg/ l foliar spray of gibberellic acid, while the lowest values were found by using flat NFT system sprayed with distilled water. This trend was true for the two seasons of study. In addition the heights total yield per m^2 was recorded with A-shape NFT system combined with 40 mg/l gibberellic acid followed by bed system combined with 40 mg/l gibberellic acid without significant difference between them (Note, the number of plants in both systems is different). On the other hand, the lowest yields per m^2 were recorded with flat NFT system without sprayed of gibberellic acid followed by combined with 10 mg/l gibberellic acid.

Effect of soilless culture systems and foliar spry of GA_3 on nitrogen, phosphorus and potassium (%) in shoot of celery plant

Data in Table (4) show that, as mentioned before with fresh and dry weight per plant, all substrate culture systems (beds, pots and horizontal bags systems) recorded increase in nitrogen, phosphorus and potassium content (%) in shoot of celery plant as compared with modified nutrient film technique systems (A-shape NFT and flat NFT systems). The highest values of these nutrients, during the two seasons, was found using beds system in comparison with other tested soilless culture systems. The lowest value was found with A-shape NFT. Also, the values obtained from the other soilless culture systems were found to be in between. These results may be due to the differences among tested soilless culture systems in the available volume of growth media, aeration and dark conditions, which affect root system development and nutrient uptake. These results were in agreement with Neveen Metwally (2016), where data indicated that increased container size from 2.5 liters, with 13cm depth in small pots system, to 5 liters, with 15cm depth in big pots system, increased NPK content in leaves of hot pepper plants grown in rooftops gardens.

Table (4) show that, increased foliar application of gibberellic acid up to 40 mg/l caused a significant increase in nitrogen, phosphorus and potassium content (%) in shoot of celery plants as compared with non foliar spray with gibberellic acid (control treatment). The highest significant values of these nutrients were recorded with high foliar application (40 mg/l), while the lowest significant values were recorded with non-spray of gibberellic acid (control treatment). Also, the values obtained from the other foliar application of gibberellic acid were found to be in between. These results were in agreement with Eid *et al*., (2006), on croton plants, where they reported that GA_3 treatment increased the absorption and accumulation of N, P, K and micronutrients in tissues of plant. Furthermore, Shah *et al*.,(2006) noted that in black cumin plant (*Nigella sativa* L), the main reason for elevated growth parameters of plants beyond GA_3 treatment was raised absorption potential and assimilation of mineral nutrients during vegetative growth stage. Hassanpouraghdam *et al.,* (2011) mentioned that, it is possible that GA_3 had the potential to accelerate the nutrients partitioning towards cells and active growth sites and concomitantly increases those nutrients absorption via increased root potential.

As for the interaction effect between soilless culture systems and foliar spray of gibberellic acid on the content of N, P and K, data revealed that, the heights content of N, P and K in shoot of celery plant were recorded with beds system combined with 40 mg/l gibberellic acid. On the other hand, the lowest values of N, P and K were recorded with A-shape NFT system at non foliar spry with gibberellic acid. This results were in agreement with Currah and Thomas (1979) on carrot plant, Abdel-Rahim and Abdel-Aziz (1983) on lettuce plant, Eid *et al*., (2006) on croton plant, Mukhtar (2008) on red sorrel plant and Hassanpouraghdam *et al.,* (2011) on lavender plant.

Table 4: Effect of different soilless culture systems and different foliar spray of GA_3 concentrations (mg/ l) on N, P and K content (%) in shoot of celery plants.

Treatments	First season			Second season		
	N	P	K	N	P	K
	Soilless culture systems					
Beds	2.18 A	0.63 A	4.19 A	2.36 A	0.61 A	4.55 A
Pots	2.14 B	0.59 B	4.17 A	2.33 A	0.58 B	4.25 B
Bags	1.94 C	0.59 B	3.39 B	2.05 B	0.57 B	3.44 C
Flat NFT	1.94 C	0.52 C	3.15 C	2.05 B	0.51 C	2.84 D
A-shape NFT	1.92 C	0.48D	2.85 D	2.00 B	0.47 D	2.78 D
	Gibberellic acid concentration					
Control	1.75 E	0.47 D	2.60 E	1.77 C	0.37 D	2.66 D
10	1.88 D	0.53 C	3.29 D	1.98 B	0.50 C	3.35 C
20	1.85 C	0.53 C	3.53 C	1.98 B	0.61 B	3.53 B
30	2.28 B	0.58 B	4.07 B	2.50 A	0.59 B	4.10 A
40	2.37 A	0.70 A	4.26 A	2.56 A	0.67 A	4.21 A

Table 4: Cont.

Treatments		First season			Second season		
		N	P	K	N	P	K
Soilless culture systems * Gibberellic acid concentration							
Beds	Control	1.76 g	0.43 ef	2.97 gh	1.79 e	0.40 de	3.14 de
	10	1.97 e	0.63 c	4.15 d	2.07 cd	0.59 c	4.49 bc
	20	1.97 e	0.63 c	4.33 cd	2.09 cd	0.61 c	4.81 b
	30	2.56 b	0.63 c	4.52 bc	2.92 a	0.67 bc	4.81 b
	40	2.65 a	0.85 a	4.97 a	2.94 a	0.80 a	5.51 a
Pots	Control	1.77 g	0.37 f	2.83 h	1.86 de	0.36 e	3.00 de
	10	1.80 fg	0.45 e	4.30 cd	1.94 de	0.45 d	4.42 c
	20	1.96 e	0.57 cd	4.40 c	2.10 cd	0.55 cd	4.46 bc
	30	2.56 b	0.72 b	4.45 c	2.85 a	0.71 b	4.59 bc
	40	2.62 ab	0.84 a	4.85 ab	2.90 a	0.81 a	4.78 bc
Bags	Control	1.73 g	0.35 f	2.40 ij	1.78 e	0.35 e	2.59 ef
	10	1.81 fg	0.54 d	2.50 ij	1.86 de	0.53 cd	2.64 e
	20	1.84 f	0.59 cd	2.59 i	2.02 d	0.57 cd	2.78 e
	30	2.10 d	0.67 bc	4.73 b	2.17 cd	0.65 bc	4.52 bc
	40	2.22 c	0.80 a	4.75 ab	2.42 b	0.76 ab	4.67 bc
Flat NFT	Control	1.75 g	0.34 f	2.37 ij	1.77 e	0.32 e	2.25 f
	10	1.84 f	0.45 e	3.07 g	1.87 de	0.44 d	2.48 ef
	20	1.82 fg	0.46 e	3.30 f	1.92 de	0.45 d	2.84 e
	30	2.10 d	0.55 d	3.45 ef	2.20 c	0.54 cd	3.17 de
	40	2.19 c	0.61 cd	3.67 e	2.39 b	0.60 c	3.28 d
A-shape NFT	Control	1.73 g	0.33 f	2.25 j	1.65 e	0.32 e	2.15 f
	10	1.83 fg	0.55 d	2.52 ij	1.93 de	0.54 cd	2.69 e
	20	1.83 fg	0.55 d	2.79 hi	1.96 de	0.56 cd	2.83 e
	30	2.09 d	0.57 cd	3.13 fg	2.24 bc	0.56 cd	3.09 de
	40	2.17c	0.58 cd	3.47ef	2.34 bc	0.59 c	3.32 d

Economic study

The economic study was calculated on the basis that the system area is 6 square meters as well as the possibility of planting celery crop is two times per season. In addition, the prices of total construction costs and total production costs were calculated according to the Egyptian market.

Total construction costs (LE)

Table (5) shows the construction costs (LE) of different soilless systems (6 m^2/ system) for celery crop under rooftop conditions during the seasons of 2015 and 2016. Data showed that the construction costs with substrate systems were higher than modified NFT systems. On the other hand, the highest value of construction costs was found with pots system (222.4 LE per season) followed by bags and beds systems (221.8 and 220 LE), respectively. While the lowest construction cost was found with flat NFT system (183.1 LE).

Table 5: Total construction costs analysis (LE) of different soilless systems (6 m^2/ system) for celery crop during one season under Egyptian condition.

System type	Pipes	Holders	Tables	Tank	Timer	Irrigation system	Pump	Substrate	Pots	Bags	Installation costs	Total construction costs
Modified NFT system												
A Shape	45	42.5	-	21	14.5	10	17.5	3.3	-	-	37.5	191.3
Flat	37.5	42.5	-	21	14.5	10	17.5	2.6	-	-	37.5	183.1
Substrate system												
Beds	-	-	81	21	14.5	5	17.5	43.5	-	-	37.5	220
Pots	-	-	81	21	14.5	5	17.5	43.5	2.4	-	37.5	222.4
Bags	-	-	81	21	14.5	5	17.5	43.5	-	1.8	37.5	221.8

Total production costs (LE)

Table (6) shows the total production costs (LE) of different soilless systems(6 m^2/ system) for celery crop under rooftop conditions during the seasons of 2015 and 2016 (two times planting per each season). Data showed that the total production costs with modified NFT systems were higher than substrate systems. The highest production costs were found with the A shape system (392 LE two times planting per season) followed by flat system (343.2 LE two times planting per season).On the other hand, the lowest total production costs were recorded with pots and bags substrate systems.

Total return

The total return from different soilless systems (6 m^2/ system) ranged between 768 and 1008 LE per season (Table7). The highest total return (1008 LE) was with A shape system and the lowest total return (768 LE) was with pots and bags systems.

Table 6: Total production costs (LE) of different soilless systems (6 m^2/ system) for celery crop under Egyptian condition during one season (two times planting).

System type	Seedling	Irrigation	Chemicals	Electricity	Others	Total production costs
Modified NFT systems						
A shape	144	6	180	12	50	392
Flat	120	5.2	156	12	50	343.2
Substrate systems						
Beds	96	5.2	156	2.4	50	309.6
Pots	96	4.8	144	2.4	50	297.2
Bags	96	4.8	144	2.4	50	297.2

Net profit

The net profit from the different soilless systems (6m^2/system) ranged between 424.7and 248.4LE per season (Table7).The highest net profit (424.7LE)was withA shape system while the lowest net profit (248.4LE) was with pots system.

Table 7: Total return and net profit (LE) of different soilless systems (6m^2/system) for celery crop under Egyptian condition during one season (two times planting).

System type	Construction costs	Production costs	Total cost	Total yield	Price per plant	Total return	Net profit
Modified NFT system							
A Shape	191.3	392	583.3	288	3.5	1008	424.7
Flat	183.1	343.2	526.3	240	3.5	840	313.7
Substrate system							
Beds	220	309.6	529.6	192	4.5	864	334.4
Pots	222.4	297.2	519.6	192	4	768	248.4
Bags	221.8	297.2	519	192	4	768	249

Price for 600 - 700 gm = 3.5 LE , Price for 700- 800 gm = 4 LE , Price for 800- 900 gm = 4.5 LE.

Conclusion

Based on the above discussion we concluded that rooftops could be used to produce some crops such as celery, whether for domestic consumption or commercial production, through different soilless systems. Using substrate systems gave the highest fresh and dry weight per plant, while modified NFT systems gave the highest yield of celery plant per Meter Square. For the commercial exploitation of rooftops to produce celery plant, the modified NFT systems are preferred because it gave the highest number of plants per Meter Square and net profit is high in comparison with substrate systems. On the other hand, when the rooftops are used for the purpose of domestic sufficiency of celery plants, the system of beds is preferred because the weight of plants is high and the cost of production is low as compared with other soilless systems. Also, it is possible to accelerate the growth of plants and increase the yield of celery crop under different soilless systems through foliar application of gibberellic acid.

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