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Potatoes Production Using Different Cultivation Systems on Rooftops

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ABSTRACT

Potatoes are one of the main consumption vegetable crops in Egypt. Rooftop potatoes production can make a big difference in increasing the availability of potatoes near consumption centers within cities, which will help bring the price down as a result to cut transportation costs. Rooftop potatoes production may also help support household self-sufficiency; that every family can produce its vegetable crop needs from their rooftop gardens. In this context, an experiment has been conducted in the rooftop garden of Central Laboratory for Agricultural Climate, Agricultural Research Center, Ministry of Agriculture and Land Reclamation, Dokki, Giza, Egypt during two successive seasons of 2020/2021 and 2021/2022 respectively. The experiment aimed to determine the suitable cultivation system and plant density for producing potatoes on rooftops using substrate mixture consisted of coco peat: perlite: sand (2:2:1 v/v/v). 2 cultivation systems (deep beds "DB" and horizontal bags "HB") and 3 planting densities (6 plants /m^2 "PD-1", 9 plants /m^2 "PD-2" and 12 plants /m^2 "PD-3") have been tested in this experiment. The experiment was arranged in split plot design with three replicates. The cultivation systems were arranged in the main plots, while planting density was arranged in the sub plots. Results indicated that for the effect of cultivation system deep beds system has proved that it's more suitable for potatoes production on roof tops than horizontal bags system; plants grown in deep beds system recorded higher values regarding plant height, number of leaves, fresh and dry weights of aerial parts, both yields per plant or m^2, average tuber weight and percentages of (nitrogen, phosphorus, potassium) in leaves. Regarding the effect of plant density, cultivate 6 plants per m^2 recorded the highest values comparing to the other tested plant densities in plant height, number of leaves, aerial parts fresh and dry weights, yield per plant, average tuber weight and (nitrogen, phosphorus, potassium) % in leaves. Nevertheless, even the yield / plant was lower in case of cultivate 9 plants /m^2 but the total yield per m^2 was higher as affected with the more plants were cultivated in m^2.

Keywords: Potatoes, cultivation systems, soilless culture, plant density, roof gardens

1. Introduction

The Agriculture production in Egypt is depends mainly on the traditional soil production methods. With the high increase in the population in Egypt a new production method must be introduced to the community to increase the food production; a new crop production method without entirely dependent on soil. These goals can be achieved using soilless culture techniques for crop production. Savvas *et al.,* (2013) identified soilless culture as a method for growing plants without the use of soil as a rooting medium, and nutrients absorbed by the roots are supplied via the irrigation water. Soilless culture offers an ideal alternative crop production for traditional soil cultivation (Olympios, 2011). Stable and high quality production is the main advantage of soilless culture (Veys, 1997). Furthermore, Grillas *et al*., (2001) mentioned that soilless culture guarantee flexibility,

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intensification and provide agricultural products with high production and quality, even in areas with adverse growing conditions. Furthermore, soilless cultivation represented a breakthrough, opportunity to achieve high yields and standardized production (Burrage, 1992).

Rooftop gardens are a specialized roofing system that supports vegetation growth on rooftops. Rooftop gardens have a long history, but today it is rapidly advancing technology that has the potential to improve the quality of life in urban area (Mander *et al.,* 2006). Furthermore, Luckett, (2009) reported that rooftop gardens contribute positively to make cities more livable. In addition, rooftop gardens can also provide farmland for local vegetable and food production, by setting up edible rooftop gardens it is possible to promote more useful and meaningful functions for the green rooftops (ARGP, 2008).

The soilless techniques can be established anywhere and it will reduce the quantity of water and fertilizer that needed to produce the same crop in soil (Al-Sadawi and Al-Sahaf, 2003). Soilless culture is the most suitable cultivation system for establish a rooftop garden; on rooftops no soil available, limited spaces, adverse production conditions. Soilless systems usually made from Light-weight materials and cultivation systems are easy to be adapted to almost any available space on rooftops. Moreover, the nutrient solution can be easily recirculated in a closed system. The excess nutrient solution collected and reused again in irrigation, this technique is important in case of rooftop gardens; it prevents the leaching of water and nutrient solution to the roof floor also save water and fertilizers (Metwally, 2016).

Potatoes (*Solanum tuberosum,* L.) is a cash crop and a significant part of the global diet; potatoes is the fourth important food crop in the world after wheat, rice and corn (FAO, 2020).

The potatoes crop is considered one of the strategic vegetable crops in Egypt, as it is one of the food and industrial crops on which some food industries are based. Egyptian, potatoes are considered one of the important export crops in terms of global demand (Salah El-Din *et al*., 2022). Increase the production of this important crop from rooftops will help in increase the total country production of potatoes by make benefits of such useless spaces like rooftops and overall this will decrease the prices of potatoes as a result of increase the availability of the crop within cities and urban areas, and cut off the cost of transportation from production areas to consumption centers in cities. For that an experiment has been done to determine the suitable cultivation system and plant density for producing potatoes on rooftops.

2. Materials and Methods

2.1. Site and plant material

An experiment has been conducted in the rooftop garden of Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center, Ministry of Agriculture and Land Reclamation, Dokki, Giza, Egypt during two successive seasons of 2020/2021 and 2021/2022.

Potatoes (*Solanum tuberosum*) variety Spunta has been used in this experiment. Systems were cultivated with potato seeds in the middle of October each season.

The experiment aimed to determine the suitable cultivation system and plant density for producing potatoes on rooftops using substrate mixture consisted of coco peat: perlite: sand (2:2:1 v/v/v).

2.2. Cultivation systems description

2.2.1. Deep beds system

The deep beds system that used in this experiment consisted of a wooden table (100cm length, 100cm width, and 20cm depth) and height of table legs was about 60cm from roof floor. The entire depth of the tables have been padded with black polyethylene sheets 0.7mm in thickness and equipped with drainage tube in one side, under this tube, plastic tank have been put under each table to collect the excess irrigation water. The entire depth of the bed has been filled with 200L of substrate mixture coco peat: perlite: sand (2:2:1 v/v/v).

2.2.2. Horizontal bags system

The horizontal bags system consisted of horizontal bags made from black on white polyethylene sheet (0.2mm thickness). Each bag filled with 30Lof substrate mixture coco peat: perlite: sand (2:2:1 v/v/v). Holes were made in the lowermost in both sides of each bag for drainage to release

the excess nutrient solution and water. Moreover, bigger holes have been made in the surface to facilitate the cultivation of potato tubers. Substrate depth was 10cm.

Drip irrigation system was used to deliver water mixed with nutrient solution to plants, and a slope about 1% have been made for collecting the drained solution and return it back to the catchment tank using the drainage tube. The composition of the nutrient solution that used in the experiment was described by (El-Behairy, 1994), electrical conductivity (EC) adjusted at the range of 2.0-2.5 m.mhos^2 throughout the experimental time.

2.3. Treatments

The experiment was consisted of two factors, their description were as follow:

Factor (A): cultivation systems

1. Deep beds system (DB).
2. Horizontal bags system (HB).

Factor (B): planting density.

1. Cultivate 6 plants per m^2 (PD-1).
2. Cultivate 9 plants per m^2 (PD-2).
3. Cultivate 12 plants per m^2 (PD-3).

2.4. Measurements

Different measurements have been recorded during the experimental time such as: plant height, number of leaves, aerial parts fresh and dry weights, yield per plant and m^2, average tuber weight and (nitrogen, phosphorus, potassium) % in leaves.

Nitrogen, phosphorus and potassium percentages in leaves were measured according to (A.O.A.C., 1990).

2.5. Experimental design and statistical analysis

The experiment was arranged in split plot design with three replicates. The cultivation systems were arranged in the main plots, while planting density was arranged in the sub plots. The collected data were analyzed using ANOVA statistical analysis as described by (Snedicor and Cochran, 1980), and means were compared by determining the least significant difference (L.S.D) at a probability level of 0.05.

3. Results

3.1. Plant height

Data in table (1) illustrate the effect of cultivation systems and plant density on plant height. Regarding the cultivation systems, data collected from both seasons indicated that potatoes plants grown in deep beds system recorded higher plant height values than those grown in horizontal bags. Moreover, the difference between both of them was significant.

Regarding the plant density, first season data indicated that PD-1 recorded the highest plant height values followed by PD-2 then PD-3 respectively. All differences among treatments were significant except the difference between PD-1 and PD-2 was not significant. Similar trend was observed in the second season except that all differences among treatments were significant.

Regarding the interaction between cultivation systems and plant density, data from first season illustrated that the interaction between deep beds and PD-1 "DB+PD-1" recorded the highest plant height values, while interaction between horizontal bags and PD-3 "HB+PD-3" recorded the lowest values. On the other hand, there were no significant differences among interactions in the second season.

Table 1: Effect of cultivation systems and plant density on plant height (cm) of potatoes grown using soilless culture technology during seasons of 2020/2021 and 2021/2022.

Cultivation systems (CS)	Plant density (PD)			Mean
	PD-1	PD-2	PD-3	
	1st season (2020/2021)			
DB	80.13	78.58	64.11	**74.28**
HB	61.04	58.37	52.77	**57.39**
Mean	**70.59**	**68.47**	**58.44**	
	2nd season (2021/2022)			
DB	82.65	76.93	70.32	**76.63**
HB	64.80	56.48	48.51	**56.60**
Mean	**73.72**	**66.71**	**59.41**	

LSD					
1st season			2nd season		
CS	**PD**	**CS*PD**	**CS**	**PD**	**CS*PD**
3.57	2.28	9.66	4.74	2.63	N.S

DB: deep beds, **HB:** horizontal bags, **PD-1**: 6 plants/ m^2, **PD-2**: 9 plants/ m^2, **PD-3**: 12 plants/ m^2.

3.2. Number of leaves

Data in table (2) illustrate the effect of cultivation systems and plant density on number of leaves. Regarding the cultivation systems, data collected from both seasons showed that deep beds system recorded higher number of leaves than horizontal bags, and the difference between both of them was significant.

Regarding the plant density, first season data illustrated that PD-1 recorded the highest number of leaves followed by PD-2 then PD-3 respectively. All differences among treatments were significant. Similar trend was observed in the second season.

Regarding the interaction, data collected from the first season illustrated that the "DB+PD-1" recorded the highest number of leaves. Otherwise, "HB+PD-3" recorded the lowest number of leaves. On the other hand, there were no significant differences among interactions in the second season.

Table 2: Effect of cultivation systems and plant density on number of leaves/ plant of potatoes grown using soilless culture technology during seasons of 2020/2021 and 2021/2022.

Cultivation systems (CS)	Plant density (PD)			Mean
	PD-1	PD-2	PD-3	
	1st season (2020/2021)			
DB	47.67	45.67	37.00	**43.44**
HB	38.67	33.33	23.67	**31.89**
Mean	**43.17**	**39.50**	**30.33**	
	2nd season (2021/2022)			
DB	46.00	43.33	39.67	**43.00**
HB	39.33	32.00	26.00	**32.44**
Mean	**42.67**	**37.67**	**32.83**	

LSD					
1st season			2nd season		
CS	**PD**	**CS*PD**	**CS**	**PD**	**CS*PD**
3.99	1.09	4.62	4.78	2.35	N.S

DB: deep beds, **HB:** horizontal bags, **PD-1**: 6 plants/ m^2, **PD-2**: 9 plants/ m^2, **PD-3**: 12 plants/ m^2.

3.3. Fresh weight of aerial parts

Data in table (3) illustrate the effect of cultivation systems and plant density on fresh weight of aerial parts. Concerning the cultivation systems, data collected from both seasons illustrated that deep beds system recorded significantly higher values for fresh weight of aerial parts than horizontal bags.

Concerning the plant density, data in the first seasons showed that PD-1 recorded the highest values for fresh weight of aerial parts followed by PD-2 then PD-3 respectively. Furthermore, differences among treatments were significant. Similar trends were observed in the second season.

Concerning the interaction, data collected from both seasons illustrated that the "DB+PD-1" recorded the highest values for fresh weight of aerial parts. Otherwise, "HB+PD-3" recorded the lowest values.

Table 3: Effect of cultivation systems and plant density on fresh weight of aerial parts/ plant (g) of potatoes grown using soilless culture technology during seasons of 2020/2021 and 2021/2022.

Cultivation systems (CS)	Plant density (PD)			
	PD-1	**PD-2**	**PD-3**	**Mean**
		1st season (2020/2021)		
DB	654.40	599.76	407.12	**553.76**
HB	436.32	396.48	303.65	**378.82**
Mean	**554.36**	**498.12**	**355.39**	
		2nd season (2021/2022)		
DB	630.70	606.55	448.74	**562.00**
HB	424.24	388.82	320.01	**377.69**
Mean	**527.47**	**497.69**	**384.37**	
		LSD		

1st season			2nd season		
CS	**PD**	**CS*PD**	**CS**	**PD**	**CS*PD**
23.73	11.34	48.12	8.31	14.09	59.78

DB: deep beds, **HB:** horizontal bags, **PD-1**: 6 plants/ m^2, **PD-2**: 9 plants/ m^2, **PD-3**: 12 plants/ m^2.

3.4. Dry weight of aerial parts

Data in table (4) illustrate the effect of cultivation systems and plant density on dry weight of aerial parts. Concerning the cultivation systems, data collected from both seasons illustrated that deep beds system recorded significantly higher values for dry weight of aerial parts than horizontal bags.

Concerning the plant density, data in the first seasons showed that PD-1 recorded the highest values for dry weight of aerial parts then PD-2 and PD-3 respectively. Moreover, differences among treatments were significant. Similar trends were observed in the second season.

Concerning the interaction, data collected from first season indicated that there were no significant differences among interactions. On the contrary, data in the second season illustrated that the "DB+PD-1" recorded the highest dry weight values, while "HB+PD-3" recorded the lowest values.

3.5. Yield per plant

Data in table (5) illustrate the effect of cultivation systems and plant density on yield per plant. For the cultivation systems, data collected from both seasons illustrated that deep beds system recorded higher yield per plant values than horizontal bags. Furthermore, the difference was significant between the both tested cultivation systems.

For the plant density, data collected from both seasons showed that PD-1 recorded the highest yield per plant values then PD-2 and PD-3 respectively. Moreover, differences among treatments were significant.

For the interaction, data collected from both seasons indicated that "DB+PD-1" recorded the highest yield per plant values. Otherwise, "HB+PD-3" recorded the lowest values.

Table 4: Effect of cultivation systems and plant density on dry weight of aerial parts/ plant (g) of potatoes grown using soilless culture technology during seasons of 2020/2021 and 2021/2022.

Cultivation systems	Plant density (PD)			
(CS)	**PD-1**	**PD-2**	**PD-3**	**Mean**
		1st season (2020/2021)		
DB	50.93	45.55	36.20	**44.23**
HB	38.65	34.75	20.08	**31.16**
Mean	**44.79**	**40.15**	**28.14**	
		2nd season (2021/2022)		
DB	60.93	51.60	39.63	**50.72**
HB	41.14	37.14	23.10	**33.79**
Mean	**51.04**	**44.37**	**31.37**	
		LSD		

1st season			2nd season		
CS	**PD**	**CS*PD**	**CS**	**PD**	**CS*PD**
6.08	3.55	N.S	3.35	1.62	6.86

DB: deep beds, **HB:** horizontal bags, **PD-1**: 6 plants/ m^2, **PD-2**: 9 plants/ m^2, **PD-3**: 12 plants/ m^2.

Table 5: Effect of cultivation systems and plant density on yield per plant (g) of potatoes grown using soilless culture technology during seasons of 2020/2021 and 2021/2022.

Soilless systems	Plant density (PD)			
(SS)	**PD-1**	**PD-2**	**PD-3**	**Mean**
		1st season (2020/2021)		
DB	695.54	594.89	361.43	**550.62**
HB	459.33	391.52	168.33	**339.73**
Mean	**577.44**	**493.21**	**264.88**	
		2nd season (2021/2022)		
DB	672.99	611.03	390.57	**558.20**
HB	431.54	402.26	188.05	**340.62**
Mean	**552.27**	**506.64**	**289.31**	
		LSD		

1st season			2nd season		
CS	**PD**	**CS*PD**	**CS**	**PD**	**CS*PD**
13.23	12.72	53.97	29.23	11.80	50.07

DB: deep beds, **HB:** horizontal bags, **PD-1**: 6 plants/ m^2, **PD-2**: 9 plants/ m^2, **PD-3**: 12 plants/ m^2.

3.6. Yield per m^2

Data in table (6) illustrate the effect of cultivation systems and plant density on yield per m^2. Regarding the effect of cultivation systems, data collected from both seasons illustrated that deep beds system recorded higher yield per m^2 values than horizontal bags. Furthermore, the difference was significant between the both tested cultivation systems.

Regarding the plant density, data collected from the first season illustrated that PD-2 recorded the highest yield per m^2 value then PD-1 and PD-3 respectively. Moreover, differences among treatments were significant. On the second season, data showed similar trend except that PD-3 recorded higher yield per m^2 than PD-1.

Regarding the interaction, data collected from both seasons illustrated that "DB+PD-2" recorded the highest yield per m^2values. Otherwise, "HB+PD-3" recorded the lowest yield values.

Table 6: Effect of cultivation systems and plant density on yield per m^2 (kg) of potatoes grown using soilless culture technology during seasons of 2020/2021 and 2021/2022.

Cultivation systems (CS)	Plant density (PD)			Mean
	PD-1	PD-2	PD-3	
		1st season (2020/2021)		
DB	4.17	5.35	4.34	**4.62**
HB	2.76	3.52	2.02	**2.77**
Mean	**3.46**	**4.44**	**3.18**	
		2nd season (2021/2022)		
DB	4.04	5.50	4.69	**4.74**
HB	2.59	3.62	2.26	**2.82**
Mean	**3.31**	**4.56**	**3.47**	
		LSD		

1st season			2nd season		
CS	**PD**	**CS*PD**	**CS**	**PD**	**CS*PD**
0.11	0.12	0.29	0.29	0.10	0.42

DB: deep beds, **HB:** horizontal bags, **PD-1**: 6 plants/ m^2, **PD-2**: 9 plants/ m^2, **PD-3**: 12 plants/ m^2.

3.7. Average tuber weight

Data in table (7) illustrate the effect of cultivation systems and plant density on average tuber weight. For the cultivation systems, data collected from both seasons indicated that deep beds system recorded higher average tuber weight values than horizontal bags. Furthermore, the difference was significant between the both tested cultivation systems.

For the plant density, data from both seasons indicated that PD-1 recorded the highest average tuber weight followed by PD-2 then PD-3 respectively. In addition, all differences among treatments were significant in both seasons.

For the interaction, data collected from both seasons illustrated that "DB+PD-1" recorded the highest average tuber weights. Otherwise, "HB+PD-3" recorded the lowest weight.

Table 7: Effect of cultivation systems and plant density on average tuber weight (g) of potatoes grown using soilless culture technology during seasons of 2020/2021 and 2021/2022.

Cultivation systems (CS)	Plant density (PD)			Mean
	PD-1	PD-2	PD-3	
		1st season (2020/2021)		
DB	98.77	83.73	69.48	**83.99**
HB	69.98	52.18	50.45	**57.54**
Mean	**84.38**	**67.95**	**59.97**	
		2nd season (2021/2022)		
DB	95.68	89.53	71.57	**85.59**
HB	72.16	55.21	54.13	**60.50**
Mean	**83.92**	**72.37**	**62.85**	
		LSD		

1st season			2nd season		
CS	**PD**	**CS*PD**	**CS**	**PD**	**CS*PD**
2.96	2.97	12.59	7.58	3.00	12.73

DB: deep beds, **HB:** horizontal bags, **PD-1**: 6 plants/ m^2, **PD-2**: 9 plants/ m^2, **PD-3**: 12 plants/ m^2.

3.8. Nitrogen % in leaves

Data in table (8) illustrate the effect of cultivation systems and plant density on nitrogen % in leaves of potatoes. Concerning the cultivation systems, both seasons' data illustrated that deep beds system recorded higher nitrogen % than horizontal bags. Furthermore, the difference was significant between the both tested cultivation systems.

Concerning the plant density, first season data illustrated that PD-1 recorded the highest nitrogen % then PD-2 and PD-3 respectively. In addition, differences among treatments were significant except the difference between PD-1 and PD-2 was not significant. On the second season, data showed similar trend except that all differences among treatments were significant.

Concerning the interaction, there were no significant differences detected among interactions in the first season. Otherwise, data collected from second season indicated that "DB+PD-1" recorded the highest nitrogen % in leaves, while "HB+PD-3" recorded the lowest nitrogen %.

Table 8: Effect of cultivation systems and plant density on nitrogen % in leaves of potatoes grown using soilless culture technology during seasons of 2020/2021 and 2021/2022.

Cultivation systems (CS)	Plant density (PD)			
	PD-1	PD-2	PD-3	mean
		1st season (2020/2021)		
DB	3.90	3.82	3.30	**3.67**
HB	3.01	2.91	2.60	**2.86**
Mean	**3.46**	**3.36**	**2.98**	
		2nd season (2021/2022)		
DB	3.78	3.67	3.12	**3.53**
HB	2.95	2.80	2.48	**2.74**
Mean	**3.37**	**3.24**	**2.80**	
		LSD		

1st season			2nd season		
CS	**PD**	**CS*PD**	**CS**	**PD**	**CS*PD**
0.29	0.14	N.S	0.11	0.06	0.24

DB: deep beds, **HB:** horizontal bags, **PD-1**: 6 plants/ m^2, **PD-2**: 9 plants/ m^2, **PD-3**: 12 plants/ m^2.

3.9. Phosphorus % in leaves

Data in table (9) illustrate the effect of cultivation systems and plant density on phosphorus % in leaves of potatoes. For the cultivation systems, both seasons' data showed that deep beds system recorded higher phosphorus % than horizontal bags. Furthermore, the difference between the both tested cultivation systems was significant.

Regarding the plant density, first season data illustrated that PD-1 recorded the highest phosphorus % in leaves then PD-2 and PD-3 respectively. In addition, differences among treatments were significant except the difference between PD-1 and PD-2 was not significant. Data showed similar trend in the second seasons except that all differences among treatments were significant.

Regarding the interaction, there were no significant differences detected among interactions in the first season. However, data collected from second season indicated that "DB+PD-1" recorded the highest phosphorus %, while "HB+PD-3" recorded the lowest phosphorus % in leaves.

Table 9: Effect of cultivation systems and plant density on phosphorus % in leaves of potatoes grown using soilless culture technology during seasons of 2020/2021 and 2021/2022.

Cultivation systems (CS)	Plant density (PD)			
	PD-1	PD-2	PD-3	Mean
		1st season (2020/2021)		
DB	0.451	0.431	0.378	**0.420**
HB	0.325	0.309	0.289	**0.308**
Mean	**0.388**	**0.370**	**0.334**	
		2nd season (2021/2022)		
DB	0.429	0.406	0.362	**0.399**
HB	0.317	0.308	0.303	**0.309**
Mean	**0.373**	**0.357**	**0.333**	
		LSD		

1st season			2nd season		
CS	**PD**	**CS*PD**	**CS**	**PD**	**CS*PD**
0.012	0.034	N.S	0.006	0.009	0.036

DB: deep beds, **HB:** horizontal bags, **PD-1**: 6 plants/ m^2, **PD-2**: 9 plants/ m^2, **PD-3**: 12 plants/ m^2.

3.10. Potassium % in leaves

Data in table (10) illustrate the effect of cultivation systems and plant density on potassium % in leaves of potatoes. Concerning the cultivation systems, data collected from both seasons indicated

that deep beds system recorded higher potassium % in leaves than horizontal bags. Furthermore, the difference between the both tested cultivation systems was significant in both seasons.

Concerning the plant density, first season data indicated that PD-1 recorded the highest potassium % followed by PD-2 then PD-3 respectively. Moreover, differences among treatments were significant. Data showed the same trend in the second seasons.

Concerning the interaction, there were no significant differences detected among interactions in both seasons.

Table 10: Effect of cultivation systems and plant density on potassium % in leaves of potatoes grown using soilless culture technology during seasons of 2020/2021 and 2021/2022.

Cultivation systems (CS)	Plant density (PD)			
	PD-1	**PD-2**	**PD-3**	**Mean**
		1st season (2020/2021)		
DB	3.99	3.72	3.14	**3.61**
HB	3.37	3.10	2.41	**2.96**
Mean	**3.68**	**3.41**	**2.78**	
		2nd season (2021/2022)		
DB	3.82	3.56	3.21	**3.53**
HB	3.19	3.02	2.57	**2.93**
Mean	**3.51**	**3.29**	**2.89**	
		LSD		
	1st season		**2nd season**	
CS	**PD**	**CS*PD**	**CS**	**PD**	**CS*PD**
0.29	0.16	N.S	0.10	0.11	N.S

DB: deep beds, **HB:** horizontal bags, **PD-1**: 6 plants/ m^2, **PD-2**: 9 plants/ m^2, **PD-3**: 12 plants/ m^2.

4. Discussion

From the above mentioned results it's clear that deep beds system has proved that it's more suitable for potatoes production than horizontal bags system; plants grown in deep beds system recorded higher values regarding plant height, number of leaves, aerial parts fresh and dry weights, yield per plant and m^2, average tuber weight and (nitrogen, phosphorus, potassium) % in leaves. This may be a result to increase the substrate depth in deep beds system (20 cm) than horizontal bags system (10 cm). The more substrate depth gave plant the opportunity to grow healthy and form bigger plants that help to produce more yields. In this context, NeSmith and Duval, (1998) reported that plants face many physiological and morphological changes in response to reduced rooting volume, which can affect transplant quality and performance; photosynthesis, leaf chlorophyll content, plant water relations, nutrient uptake, respiration, flowering, and yield all are affected by root restriction and container size. In addition, El-Behairy, (2008) reported that bigger strawberry plants produced higher yield. Moreover, Panayiotis *et al.,* (2011) studied the effect of two substrate depths (shallow = 7.5 cm and deep= 15 cm) on growth, and physiology of *Dianthus fruticosus* sub. *fruticosus*. Results indicated that plant growth was promoted by the deep substrate (15cm) throughout the entire study. As like, leaf dry weight was increased in the deeper substrate.

Regarding the effect of plant density, results indicated that cultivate 6 plants per m^2 recorded the highest values comparing to the other tested plant densities (9 and 12 plants /m^2) in plant height, number of leaves, aerial parts fresh and dry weights, yield / plant, average tuber weight and (nitrogen, phosphorus, potassium) % in leaves. In this context, Lee *et al.,* (2002) investigated the effect of using different plant densities (32, 48 and 64 plants per m^2) on growth of cut chrysanthemum. Their results illustrated that number of flowers per plant decreased when plant density was increased. Also, both Tehranifar *et al*., (2007) and Paranjpe *et al*., (2008) mentioned that low plant density increased number of leaves per plant.

Nevertheless, even the yield per plant was lower in case of cultivate 9 plants per m^2 but the total yield per m^2 was higher. This could be a result to increase number of plants per m^2, so even the yield per plant was smaller but the high number recover the reduction in yield. In this context, De Hoog *et al.,* (2001) investigated the effect of different plant densities (5, 7.5 and 10 plants per m^2) on the yield and quality of roses grown in substrate culture. Results indicated that the highest plant density gave the highest yield. Furthermore, De-Camacaro *et al.,* (2004) reported that in strawberry, yield per plant

increased by decreased plant density, but the highest yield / m^2 were obtained at the high plant density.

5. Conclusion

From the above mentioned results it could be concluded that deep beds system was more suitable for potatoes production than horizontal bags system, also cultivate 6 plants per m^2 recorded the highest values comparing to the other tested plant densities Otherwise, even the yield per plant was lower in case of cultivate 9 plants per m^2 but the total yield per m^2 was higher as affected with the more plants were cultivated in m^2.

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