Egyptian Journal of Horticulture
https://ejoh.journals.ekb.eg/

Performance of Grafted and Non-Grafted Cantaloupe Plants Undergo Different Fertilization Rates of Nitrogen, Phosphorus, and Potassium

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PROPAGATION of cucurbits via grafted seedlings exhibits an increasing trend in vegetable cultivation in Egypt. This is due to the limited cultivated area, intensive cultivation, and increasing stress leading to problems that negatively affect production. While the investigations for determining the accurate fertilization amount of the grafted plants are still scarce. Therefore, this experiment was conducted in a private farm located in Badr city, El-Behera governorate, Egypt, to evaluate the performance of non-grafted (control) and grafted cantaloupe plants (*Cucumis melo* var. cantaloupenses, cv. Marella F1 hybrid) onto four rootstock cultivars (Cobalt, Ferro, Star, and 6001) then fertilized with nitrogen (N), phosphorus (P), and potassium (K) at rates of 60, 80, 100, 120, and 140% of these nutrients recommendations for cantaloupe fertilization during the two successive growing seasons of 2018 and 2019. The results indicated that grafting cantaloupe plants onto the tested rootstocks had promoted a higher vegetative growth manifested as plant length, leaves number, shoot fresh and dry weight, stem diameter, and root dry weight, as well as raising leaves content of nitrogen, phosphorus, potassium, and the greenness index (chlorophyll readings, SPAD) along with boosting the average fruit weight, and early and total yield than the control when all were fertilized by any of the applied fertilization rates. Worthy, rootstocks of Cobalt and Ferro provided the greatest superiority in all investigated growth and fruit yield characteristics of the cantaloupe plant through fertilizing by the 140% NPK fertilization rate.

Keywords: Cantaloupe, Rootstocks, Fertilization, Growth, Yield, Quality.

Introduction

Cantaloupe fruit is one of the most important and popular vegetables grown in Egypt and it used mostly as a desert and refreshing fruit. It is rich in vitamins, minerals (especially potassium), dietary fiber, carbohydrates, antioxidant compounds such as phenolics, flavonoids (Tamer et al., 2010). Grafting is an important technique for the suitable cultivation of fruit-bearing plants in Japan, Korea and some Asian and European Countries, where intensive and continuous cultivation is performed. Grafting of vegetables was first performed in Korea and Japan in the late 1920s by grafting watermelon onto gourd rootstocks (Ashita, 1927; Yamakawa, 1983). Several researchers stated that grafting could significantly affect the vegetative growth of plants (El-Semellawy 2005, Ali 2012, Singh and Rao 2014). Furthermore, other researchers reported that rootstocks had excellent effects on scion growth. They found that grafting increased nutrients and mineral uptake, tolerance to stresses, synthesis, and translocation of water and plant hormones (Kroggel and Kubota 2017, Noor et al. 2019, and Shiwani 2020. It has been documented those rootstocks improved vegetative growth and significantly increased

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(*Received* 28/05/2021, *accepted* 10/09/2021)
DOI: 10.21608/ejoh.2021.78036.1175

the plant length in comparison to the non-grafted plants, Mahmoud 2016, Wehedy 2018, Mohamed et al. (2019). This could be due to increasing the absorption of water and nutrient by grafted plants than non-grafted plants (Abd El-Wanis et al. 2012, Mohamed et al. 2012, and Mohamed Sadi et al. 2019). Furthermore, several scientists confirmed that using different rootstocks improved the fresh and dry weight of watermelon plants while the lowest values were observed in non-grafted plants (El-Gazzar et al. 2016and Gómez et al. 2017). Regarding to, fruit quantity and quality, the different reports worldwide demonstrated that the fruit weight, total and early yields, fruit yield varied depending on both rootstock and scion types. Karaca et al. (2012), El-Gazzar et al. (2016), El-Kersh et al. (2016) and Kombo & Sari (2019). Similar findings were observed in grafted watermelon and confirmed by El-Gazzar et al. (2016) and Gómez et al. (2017).

Pulgar et al. (2000), Hu et al. (2006), Yuan et al. (2016), and Ceylan et al. (2018) declared that the NPK concentrations in melon plants could be affected by both the scion and by the rootstock-scion interaction. Nitrogenous compounds make up a significant part of the total dry weight of plants. An increase in N, P, and K supply leads to efficient carbohydrates to form protoplasm, hence increasing fruit weight and size.

An increase in N, P, and K supply leads to efficient carbohydrates to form protoplasm, hence increasing fruit weight and size. Numerous reports worldwide demonstrated that the fruit yield varied depending on both rootstock and scion types. Karaca et al. (2012), El-Gazzar et al. (2016), and Kombo and Sari (2019) studied the impact of rootstocks on the fruit yield of watermelon plants using different rootstocks. They observed that grafted plants recorded the highest values of average fruit weight, total and early yields, and non-grafted ones. Moreover, other research results showed that increasing the amount of N fertilizer had been related to increases in plant height, stem diameter, the number of plant leaves, leaves fresh weight, root length, and root fresh weight (Mirdad 2011). In additional studies to evaluate the impact of N, P, and K fertilizers and spacing on the growth and yield of watermelon (*Citrullus lanatus* L.), the findings showed a significant difference in plant height, number of leaves, number of flowers, number of fruits and the weight of fruits as compared to the control treatment (Sabo et al. 2013, Oga and Umekwe 2015, and Kacha et al. 2017). Olaniyi and Tella (2011) evaluated the application of N and K fertilizers and their combinations on Egusi melon plant growth, seed yield, and its nutritional quality. The results showed that plant stem and leave attributes, along with fruits and seeds yield and quality components, increased with increasing N and K fertilization rate and combinations. Moreover, Sabo et al. (2013), Oga and Umekwe (2015), and Kacha et al. (2017) assessed the effect of NPK fertilizer on the growth and yield of watermelon. The results showed that NPK fertilizer had a significant effect on the number of fruits and marketable fruits. The amount of fertilizing (NPK) of grafted Cantaloupe plants is still unknown.

In this regard, this study is aimed to find the proper amount of N, P, and K elements to meet the requirements of grafted Cantaloupe plants by using five rates of N, P, and K fertilization rates. The applied rates (60%, 80%, 100%, 120%, and 140%) were calculated based on the recommended fertilization for cantaloupe production under Egyptian conditions. The Mirella F1 hybrid cultivar was used to evaluate the behavior of the cantaloupe plants, which were grafted onto four rootstocks were Cobalt, Ferro, Star, and 6001, and cultivated in sandy soil.

Materials and Methods

Field experiment and treatments

The present study was carried out during the two successive seasons of 2018 and 2019 in a private farm located at Badr city, El-Behera Governorate, Egypt, to study the performance of grafted (on four rootstocks) and non-grafted (control) cantaloupe plants to 5 nitrogen (N), phosphorus (P) and potassium (K) fertilization rates. The performance of the cantaloupe plants was measured through vegetative growth, yield, and fruit quality. The used cultivar was the Marella F1 hybrid. The grafted and non-grafted cantaloupe transplants were produced in the nursery then transplanted in the field on March 4th, 2018, and February 28th, 2019. The cultivation density of the plants was 4200 plants/feddan area (4200m^2).

Plant materials

Cantaloupe cv. Marilla F1 hybrid belongs to the Galia type and produced in Netherland, imported by Rijk Zwaan Company. The rootstock's origin and source were shown in Table A.

NPK fertilization treatments

The applied N, P, and K fertilization rates were 60%, 80%, 100%, 120%, and 140%, calculated based on the recommended elements amounts for cantaloupe production under the Egyptian conditions of the experiment area. The fertilizers used are Nitrogen (N) as Ammonium nitrate (33% N), Phosphor (P) as calcium superphosphate (15% P_2O_5), and Phosphoric acid (46 % P_2O_5), and Potassium (K) as Potassium sulfate (50 % K_2O). The rates of N, P, and K were as follows:

- 60 % of N+P+K as [60 units + 45 unit + 75 units] per feddan.
- 80 % of N+P+K as [80 units + 60 units + 100 units] per feddan.
- 100 % of N+P+K as [100 units + 75 units + 125 units] per feddan, (the recommended amount of each elementas control).
- 120 % of N+P+K as [120 units + 90 units + 150 units] per feddan.
- 140 % of N+P+K as [140 units + 105 units + 175 units] per feddan.

The experiment was conducted in sandy soil. Its chemical analysis is shown in Table B. The drip irrigation method was used, and the irrigation water was supplied from an artesian well. The chemical analysis of the irrigation water was shown in Table C. During soil preparation; chicken manure had been added at a rate of 16 m^3/feddan. Also, superphosphate was added at a rate of 200 Kg/feddan.

TABLE A. Rootstock name and origin.

No.	The traditional name of rootstock	Rootstock Species and Scion	Company and origin (rejoin)	Classification
1	Ferro (Rootstocks)	C. *maxima* x C. *Moschata*	Rijk Zwaan, Netherland	Resistance of Fusarium and Verticillium Wilt
2	Cobalt (Rootstocks)	C. *maxima* x C. *Moschata*	Rijk Zwaan, Netherland	Resistance of Fusarium and Nematodes
3	Star (Rootstocks)	C. *maxima* x C. *Moschata*	New Star, India	————
4	6001 (Rootstocks)	C. *maxima* x C. *Moschata*	Nunhems, USA	Resistance of Nematodes
5	Control (Marilla scion)	————	RijkZwaan, Netherland	————

The method for grafting Cantaloupe transplants was splice grafting as described. All grafting methods involved the production of rootstocks and scions, according to Hassell et al. (2008).

TABLE B. Chemical analysis of the soil over the growing seasons of 2018 and 2019.

Season	EC (dS/m^2)	pH	Soluble cations (meq / 100g)				Soluble anions (meq / 100g)			
			K^+	Na^+	Mg^{2+}	Ca^{2+}	Cl^-	HCO_3^-	$SO4^{2-}$	CO_3^{2-}
1st season	0.43	6.4	0.1	0.81	0.11	0.28	0.23	0.22	0.85	-—
2nd season	0.44	6.38	0.12	0.8	0.16	0.27	0.24	0.2	0.91	-—

TABLE C. Chemical analysis of the irrigation water over the growing seasons of 2018 and 2019.

Season	EC (dS/m^2)	pH	Soluble cations (meq / 100g)				Soluble anions (meq / 100g)			
			K^+	Na^+	Mg^{2+}	Ca^{2+}	Cl^-	HCO_3^-	SO_4^{2-}	CO_3^{2-}
1st season	0.82	6.6	0.77	2.12	0.41	1.47	4.17	0.38	0.22	-—
2nd season	0.80	6.6	0.8	2.15	0.46	1.5	4.2	0.41	0.3	-—

TABLE D. Chemical analysis of the chicken manure over the growing seasons of 2018 and 2019.

Season	EC (ds/m^2)	pH (1:10)	C/N Ratio	O.M. %	O.C%	N %	P %	K %
1st season	1.27	6.15	18.8	21.7	12.6	0.67	0.64	1.41
2nd season	1.22	6.12	18.6	22.0	12.31	0.69	0.62	1.37

Note, C/N: carbon/nitrogen, O.M.: organic matter, O.C.: organic carbon.

Experimental design

The experiment has twenty-five treatments that combine the five transplant types (transplants grafted on four rootstocks and non-grafted ones) and the five NPK fertilization rates. The treatments were arranged in a split-plot design occupied in three replicates. The grafted transplants were devoted as main plots while the sub-plots were occupied with the NPK fertilization rates.

Agriculture practices

The experiment area was 1440 m^2. The soil was plowed three times then the cultivation lines were established at 6 m length and 1.6 m width. The chicken manure had been added to the soil (The chemical analysis of the chicken manure is present in the table, 4) and superphosphate. The area was divided into three equal replicates. Each replicate was divided into five main plots in each one transplant type had been cultivated. Each main plot was divided into five sub-main plots in each one; fertilization treatment had been applied. The sub-main plot area was 19.2 m2 (two rows 6 m length and 1.6 m width). In each sub-main plot cultivated 20 plants, the space between plants was 0.60 m. Before transplanting, the surface of the cultivation lines had been covered with double face polyethylene mulch (silver on black) of 30-micron thickness and 120 cm in width. During plant growth, the N, P, and K amount in the applied chicken manure was calculated then replenished the N, P, and K elements gradually to the element amount for each experimental treatment.The other agricultural practices were performed as recommended by the Ministry of Agriculture in Egypt for cantaloupe production.

The recorded data

Vegetative growth characters

The vegetative growth characters were recorded after 50 days from transplanting as follow:

- Plant length was measured as the average length in the five random plants chosen from each plot. The measurement was started from the ground contact point to the plant stem apex.
- The number of leaves per plant was recorded by counting fully expanded leaves on each plant.
- Shoot fresh and dry weight, and root dry weight five plants of each plot were rooted up carefully then separated roots and shoots. The weight of each was recorded directly after cutting. After which, the roots and shoots were dried separately in an electric drying oven at 70 °C until weight constant.
- Stem diameter (cm) was measured above the grafting point using a caliper.

Chemical analysis of leaves

The leaf sample involved ten leaves of the 5th leaf from the plant apex. The leaves were dried at 70 C° in an oven until weight constant, then pulverized to pass a 1 mm sieve. Dry samples of 0.1 g were taken and digested using the wet digestion method using a mixture of Sulphuric acid 98% and hydrogen peroxide 30%, as Thomas et al. (1967) described. The digestion extract was supplied for all the elements studied as follows:

- Nitrogen content (%), the Kjeldahl method was used to determine total nitrogen as described by Chapman and Pratt (1961).
- Phosphorus content (%): Spectrophotometer was used to measure phosphorus content using the ascorbic acid method A.O.A.C., (2005).
- Potassium content (%): A flame photometer was used to measure potassium, as Page etal. (1982) described.
- Leaf chlorophyll content (SPAD reading), the greening of the leaf was measured in the fourth leaf from the stem top using a chlorophyll meter device (SPAD-502 Plus) as a SPAD unit.

Yield and its components

Harvesting the fruits was begun after 90 days from transplanting at the full ripening stage of the fruits. The following parameters were collected:

- Early fruit yield was estimated as the weight of fruit per feddan of the first and second harvesting.

- Average fruit weight was calculated all over the harvesting season by diving weight on the number of fruits.
- Total yield of the fruits harvested throughout the entire season. This was calculated by transferring the total yield per feddan.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using the Co-Stat package program, Version 6.303; CoHort Software, USA. The differences between means were calculated using Duncan's Multiple.

Results

Vegetative growth parameters

The data in Table 1 showed that grafting cantaloupe plants on Ferro rootstock recorded the highest value of plant length compared to other grafted plants and control. Regarding NPK fertilization rate, the data proved that increasing fertilization rate causes increases in the plant length. The plant stem length was responded significantly to the interaction of both grafting on all rootstocks and fertilization rate, so the longest plant stem was recorded by grafting on Ferro and Cobalt rootstocks with NPK fertilization rate 140 % of the recommended NPK fertilization. Meanwhile, the least significant plant length was obtained with grafting plants on Star rootstock and non-grafted plants (control) accompanied with an NPK fertilization rate of 60 %. This trend of data was in harmony during the two growing seasons.

The data in the Table 2 illustrated that the higher significant leaves number was linked to grafting on rootstock Cobalt followed by Ferro in both seasons. The maximum number of leaves was obtained in the plants fertilized with that 140% NPK. Concerning the interaction of grafting on rootstock types and NPK fertilization rates, the greatest leaves number was produced in plants grafted onto Cobalt rootstock and fertilized by 140 % of the NPK fertilization rate. While the fewest leaves number was obtained in the non-grafted plants fertilized by 60 % of the NPK fertilization rate. It is worth noting that plant leave numbers were superior with grafting on Ferro and Cobalt rootstocks compared to Star and 6001 rootstocks under all NPK fertilization rates during the growing two seasons.

Concerning the data of plant fresh and dry weight in Tables (3 and 4), the plants grafted onto

TABLE 1. Effect of rootstock, NPK fertilization rates, and their interaction on plant length (cm) of cantaloupe plants during the 2018 and 2019 seasons.

NPK Fertili-zationrates	Rootstock types											
	1st Season						2nd season					
	Control	Rootstocks				Mean	Control	Rootstocks				Mean
		Star	6001	Ferro	Cobalt			Star	6001	Ferro	Cobalt	
60%	80.6 t	100.6 r	141.7 n	175.4 k	171.1 k	133.9 e	85.5 u	102.1 s	147.5 o	180.2 l	177.5 l	138.6 e
80%	91.1 s	135.8 o	165.5 l	213.1 g	210.2 g	163.1 d	97.5 t	137.6 p	167.5 m	218.1 g	212.3 h	166.5 d
100%	113.1q	160.5 m	193.5 i	235.1 e	233.9 e	187.2 c	115.3 r	161.7 n	198.5 j	239.1 e	238.1 e	190.5 c
120%	120.8 p	181.4 j	223.4 f	256.2bc	253.5 c	207.0 b	125.3 q	185.6 k	227.5 f	253.4 c	251.2cd	208.6 b
140%	156.7 m	201.7 h	246.4 d	263 a	260.3ab	225.6 a	159.1 n	207.2 i	247.6 d	272.0 a	267.2 b	230.6 a
Mean	112.4 e	156.0 d	194.1 c	228.5 a	225.8 b		116.5 e	158.8 d	197.7 c	232.6 a	229.2 b	

*Values followed by the same capital letter within the column or rows are not significantly different small petters for interaction according to Duncan's multiple range test.

TABLE 2. Effect of rootstock, NPK fertilization rates, and their interaction on the number of leaves/plant of cantaloupe plants during the 2018 and 2019 seasons.

NPK Fertilization rates	Rootstock types											
	1st Season						2nd Season					
	Control	Rootstocks				Mean	Control	Rootstocks				Mean
		Star	6001	Ferro	Cobalt			Star	6001	Ferro	Cobalt	
60%	102.0 t	109.1 rs	133.6p	176.5l	178l	139.8e	104.1t	111s	139.6p	180.4l	183.1l	143.6e
80%	105.7st	120.9q	163.8m	204.5j	208.8i	160.8d	108.9s	128.4q	171.3m	210.6i	212.4i	166.3d
100%	113.1r	150.4n	200.6j	246.4f	250.4f	192.2c	117.2r	158.5n	202.4j	251.9f	257.4e	197.5c
120%	143o	192.2k	231.1g	278.5d	285.3c	226b	145.1o	199.1j	238.2g	287.5c	291.5c	232.3b
140%	188.8k	215.6h	263e	293.9b	300.1a	252.3a	190.8k	222.8h	268.3d	269.1b	304.9a	256.6a
mean	130.5e	157.6d	198.4c	240b	244.5a		133.2e	164d	204c	245.3b	249.8a	

*Values followed by the same capital letter within the column or rows are not significantly different small petters for interaction according to Duncan's multiple range test.

Ferro and Cobalt rootstocks showed the highest fresh and dry weight significantly compared to grafting on other rootstocks or control. The data also illustrated that the increasing NPK fertilization rate increases plant fresh and dry weight. The highest plant fresh and dry weight were recorded with fertilization by 140% of NPK rate. The interaction of rootstock type and NPK fertilization rate significantly affected plant fresh and dry weight. The highest plant fresh and dry weight values were obtained in plants grafted onto Cobalt and Ferro rootstocks combined with 140 % of NPK fertilization rate. In contrast, the lowest value was recorded in non-grafted plants fertilized with 60% of NPK rate over the two seasons. Under all NPK fertilization rats (140, 120, 100, 80, 60 %), Ferro and Cobalt rootstocks seemed alike and higher response in plant fresh and dry weight followed by the 6001 rootstocks. Still, the Star rootstock recorded the lowest value of both fresh and dry weight per plant compared with the control.

Data in the Table 5 demonstrated that the highest values of root dry weight were obtained with the rootstocks treated with Cobalt and Ferro and the highest NPK fertilization rate (140 %). On the contrary, the lowest values were recorded with the control plants (non - grafted) fertilized with the lowest NPK fertilization rate (i.e., 60 % of the recommended requirement). All treatments of grafting cantaloupe plants increased the weight of root with all studied treatments. The lowest value was recorded with Star variety.

The results in Table 6 of the interaction of rootstocks and NPK fertilization rates revealed that grafted plants onto Cobalt or Ferro rootstocks then fertilized with the highest NPK rate (140 %) promoted the most thickened stem significantly. In contrast, the slimmest stem was obtained from non-grafted (control) plants. These data were in harmony in both studied seasons for fertilization rates and rootstocks compared with non-grafted plants.

Chemical analysis in the leaves:

Results in Tables 7, 8, and 9 proved that leaves of plants grafted onto Cobalt or Ferro rootstock had significantly higher nitrogen, phosphorus, and potassium percentages than those of other rootstocks non-grafted ones. Meanwhile, the highest nitrogen, phosphorus, and potassium values were obtained by adding NPK at 120 and 140% rates. As for combining the rootstock and NPK fertilization, the highest significant values were recorded in plants grafted onto cobalt rootstock and fertilized with NPK fertilization of 140 %, while the lowest value was noticed in a non-grafted plant and with NPK fertilization at 60 % over the two seasons.

The data in Table 10 of interactions between grafting and the rates of NPK fertilization

TABLE 3. Effect of rootstocks, NPK fertilization rates, and their interaction on plant fresh weight (kg) of cantaloupe plants during the 2018 and 2019 seasons.

NPK Fertilization rates	Rootstock types											
	1st season						2nd season					
	Control	Rootstocks				Mean	Control	Rootstocks				Mean
		Star	6001	Ferro	Cobalt			Star	6001	Ferro	Cobalt	
60%	1.1l	1.2kl	1.3j-l	1.6h-j	1.6g-i	1.4e	1.2s	1.2rs	1.4op	1.6lm	1.7l	1.4e
80%	1.2l	1.3kl	1.5ij	1.9d-g	1.9c-f	1.6d	1.2s	1.3pq	1.5mn	1.9hi	2h	1.6d
100%	1.2kl	1.4i-k	1.8e-g	2.1b-e	2.1a-d	1.7c	1.3qr	1.5n	1.9ij	2.1ef	2.1e	1.8c
120%	1.4j-l	1.8f-h	2.0b-e	2.2a-c	2.2ab	1.9b	1.4o	1.8j	2.1fg	2.2cd	2.3bc	1.9b
140%	1.7g-i	2c-f	2.2a-c	2.3ab	2.3a	2.0a	1.7k	2gh	2.2de	2.3ab	2.4a	2.1a
mean	1.3d	1.5c	1.8b	2a	2.0a		1.3d	1.6c	1.8b	2.0a	2.1a	

*Values followed by the same capital letter within the column or rows are not significantly different small petters for interaction according to Duncan's multiple range test.

TABLE 4. Effect of rootstocks, NPK fertilization rates, and their interaction on plant dry weight (g) of cantaloupe plants during the 2018 and 2019 seasons.

NPK Fertilization rates	Rootstock types											
	1st Season						2nd Season					
	Control	Rootstocks				Mean	Control	Rootstocks				Mean
		Star	6001	Ferro	Cobalt			Star	6001	Ferro	Cobalt	
60%	103.4s	113.5r	123.1pq	140.2lm	143.3kl	124.7e	106.3r	116.3q	125.1op	142.1kl	145.7jk	127.1e
80%	107.3s	119.1qr	134.3mn	164.8h	167.5h	138.6d	109.4r	120.6pq	136.6lm	166h	169.3gh	140.4d
100%	118.1qr	130no	158.3i	177.3ef	180.7de	152.9c	118.5pq	133.6mn	163.3h	179.6ef	183.8de	155.8c
120%	126.8op	151.6j	174.2fg	189.0bc	191.4a-c	166.6b	129.5no	154.8i	176.2f	190.7bc	192.7a-c	168.8b
140%	147.1jk	170.4gh	185.7cd	193.4ab	197.3a	178.8a	150.5ij	173.9fg	187.1cd	195.9ab	199.1a	181.3a
mean	120.5d	136.9c	155.1b	172.9a	176.0a		122.9d	139.8c	157.7b	174.8a	178.1a	

*Values followed by the same capital letter within the column or rows are not significantly different small petters for interaction according to Duncan's multiple range test.

TABLE 5. Effect of rootstock, NPK fertilization rates, and interaction on root dry weight (g) of cantaloupe plants during the 2018 and 2019 seasons.

NPK Fertilization rates	Rootstock types											
	1st Season						2nd season					
	Control	Rootstocks				Mean	Control	Rootstocks				Mean
		Star	6001	Ferro	Cobalt			Star	6001	Ferro	Cobalt	
60%	2.9p	3op	3.4l-p	3.9i-l	4.1i-l	3.5 e	2.9p	3.0op	3.5l-p	4j-m	4.1i-l	3.5 e
80%	2.9op	3.2m-p	3.8j-m	4.8e-h	4.9d-g	3.9 d	2.9p	3.3m-p	3.9j-m	4.8f-h	5e-g	4.0 d
100%	3.1n-p	3.7k-n	4.6f-i	5.2b-f	5.4a-e	4.4 c	3.1n-p	3.7k-n	4.7f-i	5.3b-f	5.4a-e	4.4 c
120%	3.6k-o	4.4g-j	5.1b-f	5.7a-c	5.8ab	4.9 b	3.6l-o	4.5g-j	5.2c-f	5.8a-c	5.9ab	5.0 b
140%	4.2h-k	5.0c-f	5.6a-d	5.9a	6.0a	5.3 a	4.3h-k	5.1d-f	5.6a-d	6a	6.0a	5.4 a
mean	3.3 d	3.9 c	4.5 b	5.1 a	5.2 a		3.4 d	3.9 c	4.6 b	5.2 a	5.3 a	

* Values followed by the same capital letter within the column or rows are not significantly different small petters for interaction according to Duncan's multiple range test.

TABLE 6. Effect of rootstock, NPK fertilization rates, and interaction on stem diameter (cm) of cantaloupe plants during the 2018 and 2019 seasons.

NPK Fertilization rates	Rootstock types											
	1st season						2nd season					
	Control	Rootstocks				Mean	Control	Rootstocks				Mean
		Star	6001	Ferro	Cobalt			Star	6001	Ferro	Cobalt	
60%	1.0 r	1.2 p	1.4 n	1.8 j	1.8 j	1.4 e	1.0 t	1.2 r	1.5 o	1.8 m	1.9 l	1.5 e
80%	1.0 q	1.3 o	1.7 k	2.2 f	2.2 f	1.7 d	1.1 s	1.4 p	1.8 m	2.2 hi	2.2 gh	1.7 d
100%	1.2 p	1.6 l	2.1 g	2.5 d	2.5 d	2.0 c	1.3 q	1.6 n	2.1 ij	2.5 e	2.6 e	2.0 c
120%	1.5 m	2.1 h	2.3 e	2.7 b	2.8 b	2.3 b	1.6 n	2.1 j	2.4 f	2.7 cd	2.8 bc	2.3 b
140%	2.0 i	2.3 e	2.6 c	2.8 a	2.9 a	2.5 a	2.0 k	2.3 fg	2.7 d	2.9 ab	2.9 a	2.5 a
mean	1.3 e	1.7 d	2.0 c	2.4 b	2.4 a		1.4 e	1.7 d	2.1 c	2.4 b	2.5 a	

* Values followed by the same capital letter within the column or rows are not significantly different small petters for interaction according to Duncan's multiple range test.

TABLE 7. Effect of rootstock, NPK fertilization rates, and interaction on total nitrogen (%) of cantaloupe plants during the 2018 and 2019 seasons.

NPK Fertilization rates	Rootstock types											
	1st season						2nd season					
	Control	Rootstocks				Mean	Control	Rootstocks				Mean
		Star	6001	Ferro	Cobalt			Star	6001	Ferro	Cobalt	
60%	1.8t	1.9st	2.3pq	3.0mn	3.0m	2.4e	1.8r	2.0qr	2.3no	3.0l	3.1l	2.4e
80%	2.1rs	2.2qr	2.8n	3.5ij	3.6hi	2.8d	2.1pq	2.2op	2.9l	3.6hi	3.7gh	2.9d
100%	2.4op	2.5o	3.4jk	4.1de	4.1de	3.3c	2.5mn	2.6m	3.5ij	4.1d-f	4.2de	3.4c
120%	3.2l	3.3kl	4.0ef	4.4bc	4.5b	3.9b	3.3k	3.3jk	4.1ef	4.4c	4.5bc	3.9b
140%	3.8gh	3.9fg	4.3cd	4.5ab	4.7a	4.2a	3.8g	3.9fg	4.3cd	4.6ab	4.8a	4.3a
mean	2.6c	2.8c	3.4b	3.9a	4.0a		2.7c	2.8c	3.4b	4.0a	4.1a	

*Values followed by the same capital letter within the column or rows are not significantly different small petters for interaction according to Duncan's multiple range test.

TABLE 8. Effect of rootstock, NPK fertilization rates, and their interaction on total phosphorus (%) of cantaloupe plants during the 2018 and 2019 seasons.

NPK Fertilization rates	Rootstock types											
	1st season						2nd season					
	Control	Rootstocks				Mean	Control	Rootstocks				Mean
		Star	6001	Ferro	Cobalt			Star	6001	Ferro	Cobalt	
60%	0.2v	0.3u	0.3r	0.4q	0.4q	0.3e	0.2x	0.3w	0.4t	0.4s	0.4s	0.3e
80%	0.23t	0.3s	0.5n	0.6m	0.6l	0.4d	0.3v	0.3u	0.5p	0.6o	0.6n	0.5d
100%	0.4p	0.4o	0.7i	0.7h	0.7h	0.6c	0.4r	0.4q	0.7k	0.7j	0.7i	0.6c
120%	0.6k	0.6j	0.8f	0.8d	0.8c	0.7b	0.6m	0.6l	0.8g	0.8e	0.8d	0.7b
140%	0.7g	0.8e	0.9b	0.9a	0.9a	0.8a	0.8h	0.8f	0.9c	0.9b	0.9a	0.9a
Mean	0.5e	0.5d	0.6c	0.7b	0.7a		0.5e	0.5d	0.6c	0.7b	0.7a	

*Values followed by the same capital letter within the column or rows are not significantly different small petters for interaction according to Duncan's multiple range test.

TABLE 9. Effect of rootstock, NPK fertilization rates, and their interaction on total potassium (%) of cantaloupe plants during the 2018 and 2019 seasons

NPK Fertilization rates	Rootstock types											
	1st Season						2nd season					
	Control	Rootstocks				Mean	Control	Rootstocks				Mean
		Star	6001	Ferro	Cobalt			Star	6001	Ferro	Cobalt	
60%	1.1m	1.1lm	1.1lm	1.2j-m	1.2i-l	1.2e	1.2i-m	1.1m	1.2lm	1.2j-m	1.2h-m	1.2d
80%	1.1lm	1.1lm	1.2k-m	1.3g-i	1.3gh	1.2d	1.1m	1.2lm	1.2k-m	1.3f-j	1.3e-i	1.2d
100%	1.2k-m	1.2k-m	1.3g-i	1.4de	1.4cd	1.3c	1.2lm	1.2k-m	1.3f-k	1.4c-e	1.4b-d	1.3c
120%	1.2h-k	1.2h-j	1.4d-f	1.5a-c	1.5a-c	1.6b	1.2g-m	1.3f-l	1.4d-f	1.5a-c	1.5ab	1.4b
140%	1.3f-h	1.3e-g	1.5bc	1.5ab	1.6a	1.4a	1.3e-h	1.3d-g	1.5bc	1.5ab	1.6a	1.5a
mean	1.2c	1.2c	1.3b	1.4a	1.4a		1.2c	1.2c	1.3b	1.4a	1.4a	

*Values followed by the same capital letter within the column or rows are not significantly different small petters for interaction according to Duncan's multiple range test.

showed a significant effect on leaf chlorophyll content indicator (SPAD reading). Therefore, the highest chlorophyll content indicator value was recorded with the interaction of grafting on the Cobalt rootstock and 140% fertilization rate. Meanwhile, The least leaf greenness data was collected on plants of control and others grafted on the Star rootstock, all fertilized by any tested fertilization rate.

Yield and its components

Data in the Table 11 showed that cantaloupe plants grafted onto different rootstocks significantly produced a higher amount of early yield than those plants grown without grafting. The highest values of the early yield were obtained by increasing the NPK rate. The grafted plants onto cobalt or Ferro rootstocks and NPK fertilization rate of 140% improved the early yield.

Table 12 showed that all grafting on the tested rootstocks increased the average fruit weight compared to the non-grafted plants. It could be deduced that with the increase of the levels of NPK, the average fruit weight increases. Referring to the impact of the interaction between grafting and NPK fertilization rates, the data illustrated that grafting on cobalt rootstock then fertilizing with the highest NPK fertilization rate (140%) significantly produced the heaviest fruits (835.1 and 849.4 g, respectively) during the two seasons compared to other interaction treatments.

Data in the Table 13 proved that grafting cantaloupe plant onto Cobalt rootstock increased total yield in the first and second seasons. Adding the NPK at 140 % was the best rate to produce the highest total yield compared with other levels in both seasons. The graft combination of Cobalt or Ferro rootstocks and NPK fertilization rate at the highest significantly produced the greatest total yield per feddan compared with non-grafted plants. In comparison, Star rootstock recorded the lowest total yield per feddan under the same NPK fertilization rates.

Discussion

The results of this investigation proved that grafting cantaloupe plants on most of the tested rootstocks improved the construction of the root system inferred from root dry weight (Table 5), so it recorded 5.2 g and 5.3 g in the grafted plants compared to 3.3 and 3.4 in the non-grafted others, in the first and second seasons, respectively. Improving root construction enabled the plant to absorb more water and nutrients,increasing the nutrients contained in the leaves (tables 7, 8, and 9). Also, grafting the cantaloupe plants increased the leaf greenness denoted as chlorophyll SPAD reading (Table 10). These effects furnish more photosynthesis assimilation reflected in plant growth as plant length, the number of leaves per plant, and plant fresh and dry weight (Tables 1,2,3, and 4). Otherwise, as in Table 6, the grafted cantaloupe plants possessed thickened stem base enabling transmitting water and nutrients along with other substances were synthesized in the roots to the aerial plant parts where improve the growth of plant organs and performance of photosynthesizes instruments. According to Venema et al. (2017) and Kyriacou et al. (2020), rootstock traits affect the scion performance through several connection mechanisms that could be categorized as physical, chemical, and physiological methods that adjust the scion responses to the environment then finally increase shoot growth in grafted plants compared to non-grafted others. Edelstein (2004) cited that grafting cucurbit on vigorous rootstocks make them withstand improper circumstances. The result of this investigation is following those found by Abd El-Wanis et al. (2012) on cucumber, and El-Kersh et al. (2016), and Wehedy (2018) on watermelon.

The data of the current experiment emphasize that grafting cantaloupe plants on most of the tested rootstocks conferred a highlight increase in the fruit yield as an increase in average fruit weight (Table 12) and early and total yield per feddan (Table 11 and 13) compared to non-grafted others. These results are in the same line with the findings of Lee et al. (2010). It is well known that the increase in the yield is due to the increase in fruit weight and/or increase in fruit number. As shown in the Tables (1-4), grafting cantaloupe plants on numerous tested rootstocks increase biomass production increased plant length and stems number, bearing the fruits, thus increasing fruit yield. Leonardi et al. (2017) reported that grafting melon on Cucurbita rootstocks increased the fruit yield compared with self-scion plants. This is due to increasing the fruit number even if the fruit's average weight is equal.

In this investigation, applying NPK fertilization at rates 60, 80, 100, 120, and 140% of the required rate facilitated the nutrients around the root area; this was more pronounced with the higher NPK rate. Thus, the root absorption rate of water and nutrients increased. This resulted in increasing the leaf nutrient content (Tables 7, 8, and 9). The increment of water and nutrient uptake improved the photosynthesis represented by total chlorophyll content (SPAD reading), increasing the plant growth as plant length, the number of leaves per plant, stem diameter, and plant fresh and dry weight (tables 1,2,3,4, 6, and 10). All these factors resulted in the improvement of the fruit quality and the total yield. The same results were consistent with Colla et al. 2010 and Kroggel and Kubota, 2017 and Abd El-All (2019).

As for Nitrogen (N) fertilization, it plays an important role in the synthesis of plant constituents through the action of different enzymes. It is a structural element of chlorophyll, amino acids in protein molecules, and impacts the formation of chloroplasts and chlorophyll accumulation in them (Edwards et al., 2004). Phosphorus (P) is required in large quantities in young cells, such as shoots and root tips, where metabolism is high, and cell division is rapid. It is essential for root growth, phosphoproteins, phospholipids, ATP, and ADP formation (Khalid, 2013). Concerning Potassium (K), it is an important macronutrient and the most abundant cation in higher plants. Potassium has been the target of some researchers mainly because it is essential for enzyme activation (Adebooye and Oloyede, 2007) (El-Bassiony et al., 2010; Janušauskaite and Feiziene, 2012 and Theago et al. 2014).

Combining rootstocks and NPK fertilization with different rates resulted in the spread of the roots and the increase in the root absorption area. This causes an increase in the water and nutrients uptake. Thus, the plant growth and the nutrient elements increased significantly. This produced more yield represented in early fruit yield, average fruit weight, and total yield per feddan (tables 11, 12, and 13) than those of conventional plants, the non-grafted ones, and the plants fertilized with the half dose of NPK. Both grafting, and NPK fertilization played a joint role in the form of a direct relationship to increase the yield of the cantaloupe plants, and these are consistent with the findings of the results, according to (Collaet al. 2010 and Kroggel and Kubota, 2017).

In conclusion, we can assure that grafting played a significant role in increasing the plants' response to the NPK fertilization rates causing the increase in the vegetative growth, represented in the increase in the number of branches, the area of leaves, and the number and size of the fruits. Both grafting and NPK fertilization played a joint role in forming a direct relationship to increasing the yield of the cantaloupe plants (Colla et al. 2010 and Kroggel and Kubota, 2017). These are consistent with the findings of our results.

TABLE 10. Effect of rootstock, NPK fertilization rates, and interaction on total chlorophyll content (SPAD) of cantaloupe plants during the 2018 and 2019 seasons.

NPK Fertilization rates	Rootstock types											
	1st Seasons						2nd Seasons					
	Control	Rootstocks				Mean	Control	Rootstocks				Mean
		Star	6001	Ferro	Cobalt			Star	6001	Ferro	Cobalt	
60%	40.8n	41n	50.4j	53.5g	53.2g	47.8e	41.0q	41.3pq	50.8k	54.3g	53.3h	48.1e
80%	42.9m	42.8m	52.0h	56.1e	55.5e	49.9d	43.1o	41.9p	52.3i	56.8e	55.9f	50d
100%	46.3l	45.7l	53.2g	58.1cd	57.7d	52.2c	45.4n	46.0n	53.4h	58.7c	58.1d	52.3c
120%	49.6j	48.7k	54.5f	60.7b	58.5c	54.4b	49.8l	48.7m	54.4g	61.0b	59.1c	54.6b
140%	51.1i	50.3j	54.4f	60.6b	61.6a	55.6a	51.6j	50.3kl	54.9g	61.6b	62.9a	56.3a
mean	46.2d	45.7e	52.9c	57.8a	57.3b		46.2d	45.6e	53.1c	58.5a	57.9b	

*Values followed by the same capital letter within the column or rows are not significantly different small petters for interaction according to Duncan's multiple range test.

TABLE 11. Effect of rootstock, NPK fertilization rates and their interaction on early fruit yield (ton/fed.) of cantaloupe plants during the 2018 and 2019 seasons.

NPK Fertilization rates	Rootstock types											
	1stSeason						2ndSeason					
	Control	Rootstocks				Mean	Control	Rootstocks				Mean
		Star	6001	Ferro	Cobalt			Star	6001	Ferro	Cobalt	
60%	2.2v	2.9t	3.4q	4.5m	4.6l	3.5e	2.3u	2.9s	3.6q	4.6m	4.7l	3.6e
80%	2.5u	3.3r	4.3n	5.7h	5.9g	4.3d	2.6t	3.3r	4.3n	5.8h	5.9g	4.4d
100%	3.2s	4.0o	5.52i	6.4e	6.5e	5.1c	3.2r	4.1o	5.6i	6.5e	6.6e	5.2c
120%	3.7p	5.2j	6.28f	6.9c	7.0b	5.8b	3.8p	5.3j	6.3f	6.9c	7.0bc	5.9b
140%	5.0k	6.2f	6.72d	7.1ab	7.1a	6.4a	5.1k	6.2f	6.8d	7.1ab	7.2a	6.5a
mean	3.3e	4.3d	5.24c	6.1b	6.2a		3.4e	4.4d	5.3c	6.2b	6.3a	

*Values followed by the same capital letter within the column or rows are not significantly different small petters for interaction according to Duncan's multiple range test.

TABLE 12. Effect of rootstock, NPK fertilization rates, and their interaction on average fruit weight (g) of cantaloupe plants during the 2018 and 2019 seasons.

NPK Fertilization rates	Rootstock types											
	1stSeason						2ndSeason					
	Control	Rootstocks				Mean	Control	Rootstocks				Mean
		Star	6001	Ferro	Cobalt			Star	6001	Ferro	Cobalt	
60%	361.8 v	384.6 t	445.1 q	588.1 m	616.9 l	479.3 e	364.1 w	396.5 u	453.6 r	594.4 n	637.6 m	489.3 e
80%	373.9 u	427.6 r	535.2 n	745.1 i	764.8 h	569.3 d	378.7 v	436.7 s	544.4 o	747.2 j	767.9 i	574.9 d
100%	402.0 s	518.1 o	738.7 i	806.9 e	810.2 e	655.2 c	412.3 t	527.9 p	741.9 jk	808.9 fg	812.1 ef	660.6 c
120%	471.8 p	684.2 j	798.1 f	820.4 cd	824.2bc	719.7 b	492.8 q	735.5 k	803.3 g	821.1 d	826.9 bc	735.9 b
140%	641.7 k	783.7 g	814.1 de	829.7 ab	835.1 a	780.8 a	653.0 l	794.6 h	817.3 de	833.4 b	849.4 a	789.0 a
mean	450.2 e	559.6 d	666.2 c	758.0 b	770.2 a		460.2 e	578.2 d	672.1 c	761.0 b	778.8 a	

*Values followed by the same capital letter within the column or rows are not significantly different small petters for interaction according to Duncan's multiple range test.

TABLE 13. Effect of rootstock, NPK fertilization rates, and their interaction on fruit yield (ton/fed.) of cantaloupe plants during the 2018 and 2019 seasons.

NPK Fertilization rates	Rootstock types											
	1st Season						2nd season					
	Control	Rootstocks				Mean	Control	Rootstocks				Mean
		Star	6001	Ferro	Cobalt			Star	6001	Ferro	Cobalt	
60%	5.3r	8.9p	12.2n	13.8k	14.6j	11.0e	5.1s	9.5q	12.3o	14.55l	14.7kl	11.3e
80%	5.7q	9.9o	12.9l	15.0h-j	15.2g-i	11.8d	6.1r	10.5p	13.5m	15.14hi	15.4gh	12.1d
100%	9.6o	12.7lm	14.9ij	15.7ef	16.0e	13.8c	9.7q	12.7n	15.0ij	15.81e	16.2d	13.9c
120%	12.4mn	14.8ij	15.6e-g	16.7cd	17.0bc	15.3b	12.6no	14.9jk	15.7ef	16.83c	17.2b	15.4b
140%	14.7j	15.4f-h	16.5d	17.3ab	17.6a	16.3a	14.8j-l	15.5fg	16.6c	17.50a	17.3a	16.4a
mean	9.5e	12.3d	14.4c	15.7b	16.1a		9.6e	12.6d	14.6c	16.0b	16.2a	

*Values followed by the same capital letter within the column or rows are not significantly different small petters for interaction according to Duncan's multiple range test.

Conclusion

The main objective of this study is to overcome the problems that limit cantaloupe growth and yielding, whether due to the soil or the surrounding environmental conditions. Therefore, the grafting and fertilization treatments were used as basic factors to achieve the goal of this study. The results confirmed that grafting became imperative to the successful cultivation of cantaloupe to overcome the risk of soil problems and altered environmental conditions. Where using grafted seedlings for cantaloupe cultivation boosted plant growth and increased fruit yield compared with non-grafted plants. Increasing plant growth and productivity due to grafting becomes need more fertilization amount; thus, using fertilization rates higher than recommended of NPK becomes imperative to meet plant needs to increase growth and yield.

Acknowledgments

We thank S. A. AbdElhady, S. M. El-Meniawy and M. E. Ragab for valuable comments and discussions of the manuscript

Funding

The study was financially support by the corresponding author Yassin Goda

Conflict of interest

The authors declare that they have noconflict of interest.

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تقييم أداء نباتات الكنتالوب المطعومة و غير المطعومة عند معاملتها بمستويات التسميد المختلفة من النيتروجين و الفسفور و البوتاسيوم

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يظهر انتشار زراعة القرعيات باستخدام عمليات التطعيم اتجاهاً متزايداً في الزراعة المصرية خاصة في حالة المساحة الزراعية المحدودة والتكثيف الزراعي وزيادة الضغوط التي تؤدي إلى مشاكل تؤثر سلباً على الإنتاج. لذلك أجريت هذه التجربة في مزرعة خاصة تقع في مدينة بدر بمحافظة البحيرة بمصر ، لتقييم أداء الكنتالوب تارة بدون تطعيم واخرى باستخدام التطعيم على اربعة جزور هجينة (كوبالت ، فيرو ، ستار و ٦٠٠١) في ظل معدلات التسميد بالنيتروجين (N) والفوسفور (P) والبوتاسيومبمعدلات مختلفة ٦٠ و ٨٠ و ١٠٠ و ١٢٠ و ١٤٠٪ من متطلبات العناصر الغذائية خلال موسمي النمو المتتاليين ٢٠١٨ و ٢٠١٩.

وقد أشارت النتائج إلى أن نباتات الكنتالوب المطعومه على الأصول المختبرة أدت الى زيادة النمو الخضري المعبر عنه بطول النبات وعدد الأوراق ووزن النبات الطازج والجاف وقطر الساق ووزن الجذرالجاف. كما أدى التطعيم إلى زيادة محتوى الأوراقمن النيتروجين والبوتاسيوم والفسفور ومؤشر الكلوروفيل الكلي (قراءة اسباد) جنبًا إلى جنب مع زيادة متوسط وزن الثمار المحصول المبكر والكلي مقارنة بالنباتات الغير مطعومه مع ثبات معدل التسميد. ومما هو جدير بالذكر فقد حقق التطعيم على الأصل الكوبالت والفيرّو افضل نتائج فى كل الصفات المختبرة لنباتات الكنتالوب من خلال التسميد بمعدل تسميد (١٤٠٪) من النيتروجين والفوسفور والبوتاسيوم.