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Growth behaviour and fruit productivity of watermelon as an affected with grafting onto different rootstock genotypes

Abd El-Mageed M. H., Ahmad M. E., Younes N. A.*

Horticulture Department, Faculty of Agriculture, Al-Azhar University, Assiut, Egypt

Abstract

The experiments were conducted on watermelon (*Citrullus lanatus* L.) at an a private farm in Awlad Amr village, Qena city, Qena, Egypt located between 26° 10′ 0″ N, 32° 43′ 0″ E during the two consecutive spring-summer seasons of 2018 and 2019 respectively to study the effect of three different genotypes used as rootstocks on plant growth performance, fruit yield and quality of three watermelon F_1 hybrids. Tongue approach grafting method was used, three hybrids of watermelon which growing on a large scale of the commercial production of watermelons in Egypt namely, Aswan F_1, Misr1 F_1 and Star F_1 was grafted onto three different genotype rootstocks i.e. Cobalt F_1, Ferro F_1 and New Star F_1. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Calculated data revealed that, there are clear significant differences between the grafted and non-grafted plants. Results of yield characteristics and its component, such as fruit weight, fruits length and circumferences and total fruit yield per feddan (ton) (feddan = 0.420 hectares = 1.037 acres), indicated to the superiority of the Misr 1 F_1 hybrid which grafted onto Cobalt F_1 rootstock, followed by the Aswan F_1 when grafted onto Cobalt F_1 rootstock. On the other side, Ferro F_1 rootstock was poorly adapted with the all commercial hybrids of watermelon under studies.

Keywords: watermelon, rootstock, grafting, tongue approach.

*Corresponding author: Younes N. A.,
E-mail address: nabel_aly77@yahoo.com

1. Introduction

Watermelon (*Citrullus lanatus* L.) a, is herbaceous creeping plant belong to the family cucurbitaceae. It is mainly propagated by seeds and thrives best in warm areas. It is a tropical plant and requires a lot of sunshine and high temperature of over 25°C for optimum growth. Watermelon thrives best in a drained fertile soil of fairly acidic nature. The fruit *Citrullus lanatus* carried 92% water by weight and about 6% sugar. It is a very good source of vitamin A, B and C which is necessary for energy production (Alka *et al*., 2018). *Citrullus lanatus* (watermelon) produces a fruit that is about 93% water, hence the name “water” melon. The “melon” part came from the fact that the fruit is large and round and has a sweet, pulpy flesh. The scientific name of the watermelon is derived from both Greek and Latin roots. The *Citrullus* part comes from a Greek word “citrus” which is a reference to the fruit. The *lanatus* part is Latin, and has the meaning of being wooly, referring to the small hairs on the stems and leaves of the plant (Baker *et al*., 2002). Watermelon (*Citrullus lanatus* Thumb.) is one of the important vegetable crops in Egypt. The major nutritional components of the fruit are carbohydrates, vitamin A and lycopene, and anti-carcinogenic compound found in red flesh watermelon. Lycopene may help reduce the risk of certain cancer of prostate gland, pancreas and stomach. The total watermelon cultivated area in 2019 in Egypt, was 120,236 fed., which produced 1583918 tons with average 13.17 ton/fed**.,** (FAO, 2019). Vegetable production using grafted plants was first initiated in Japan and Korea in the late 1920s. Grafting has become popular especially in fruit-bearing vegetables grown in greenhouses. In 1990, the area using grafted plants accounted for 59% of the production area of watermelons, cucumbers, eggplants, tomatoes and melons. Grafting is very effective to control soil-borne diseases and nematodes (Oda, 1995). High, year-round demand, increased production intensity without crop rotation, and the loss of Methyl Bromide as a soil fumigant, results in unfavorable soil conditions with increased soil pathogen populations for growing watermelon (*Citrullus lanatus* Thunb, Matsum and Nakai). Recently, many rootstocks that can be used in grafting process have spread. Certain rootstocks have superior growth habits, disease and insect resistance, and better anchorage. For example, when used as rootstock for commercial apple varieties, some rootstocks can increase resistance to crown gall and root aphids. Some are also used as dwarfing rootstocks. Grafting is an eco-friendly technique which promotes organic vegetable production. In India, Grafting can also helps in the reduction of the problems created by vegetables industry and also reduced the use of fertilizers and pesticides leads to increases in yield and quality of produced also improved. In addition, grafting application helps in reducing in the occurrence of soil borne infections leads to reduction in toxicity level vegetables and environmental pollution (Thakur and Savita, 2020**)**. Grafting is an important integrated pest management strategy to manage soil borne pathogens and other pests of solanaceous and cucurbitaceous crops. Important diseases managed by grafting are caused by fungal pathogens such as *Verticillium*, *Fusarium*, *Pyrenochaeta* and *Monosporascus* (Louws *et al*., 2010). Vegetable production with grafted seedlings was originated in Japan and Korea to avoid the serious crop loss caused by infection of soil-borne diseases aggravated by successive cropping. This practice is now rapidly spreading and expanding over the world. Vegetable grafting has been safely adapted for the production of organic as well as environmentally friendly produce and minimizes uptake of undesirable agrochemical residues (Mohamed *et al*., 2014). Grafting is a method which is done in tomato used for solving the problems caused by insect pests, occurrence of weeds and diseases like late blight and Fusarium wilt due to this yield will be reduced (Pogonyi *et al*. 2005). Grafting is done to control Fusarium wilt and tolerant to drought and flooding. Currently, in cucurbitaceous family watermelon is one crop in which grafting is practiced in the world (Yetisir *et al.*, 2003). Production of vegetables via grafting in Egypt is still in the primary stage. Cucurbits mainly watermelon presents the common vegetables that were propagated through grafted transplants. Under Egyptian conditions, although the higher cost of propagation of watermelon through grafted transplants, the farmers resorted to grafting watermelon to face many problems may severely decline watermelon cultivation area. Increase chemical pollution of soil and water and scarcity of the displayed virgin soil or limited availability of arable land attribute to increase the demand on grafted transplants for watermelon cultivation. Generally, apply grafting in vegetables cultivation in Egypt considers a new and promising practice (El-Kersh *et al*., 2016). Fruit quality and salinity conditions can be improved by grafting method. Yetisir *et al.* (2003) observed that, grafting helps in changing the quality of watermelon i.e. fruits size, texture or TSS content mostly depends on which type of rootstock is used. When brinjal grafted on gave negative effect on firmness of fruits, content of vitamin C but generally their contribution was not very much successful (Arvanitoyannis *et al.*, 2005). Davis *et al.* (2008) reported that sugars accumulate in the fruit toward the end of fruit development and ripening, depending upon the rootstock–scion combination, while the fruits of grafted and non-grafted plants acquire their rind color at about the same time. This result in growers harvesting too early and those early-harvested fruits tend to be less sweet and have a squash-like flavor. With the help of grafting the content of Sugar, carotene, flavor, color, texture can be affected. Di-Gioia *et al.* (2010) concluded this with the help of grafting there is change in TSS content when tomato “Oxheart” grafted with *Solanum lycopersicum* × *Solanum habrochiates* and also found that if tomato plants grafted onto Beaufort F_1 and Maxifort F_1 vitamin C content was decreased by 14-20%. According to Flores *et al.* (2010), the quality of fruits present on shoot is mainly dependent on the structures of root system. Gebologlu *et al.* (2011) observed that when tomato grown in soil less cultivation then due to these grafted plants gives higher marketable yield, fruit quality. Overall, most rootstocks, except bottle gourd, have been reported to increase watermelon fruit flesh firmness, total soluble solids (TSSs), and lycopene content compared to nongrafted fruit (Alan *et al*., 2007; Bruton *et al*., 2009; Kyriacou *et al*., 2016). Pinki *et al*. (2020) reported that, grafting can effectively mitigate the adverse effects of environmental stress on watermelon production. Rootstock/scion combinations can influence stress tolerance of grafted plants under different environmental conditions. Hormonal signalling plays an important role in graft union formation, rootstock–scion communication, growth and yield, and potential flowering and fruit quality. Fruit quality measures can be confounded by non-standardization of harvest maturity of grafted and nongrafted plants, and there is need for further research regarding timing of maturation to optimize fruit quality of grafted watermelon. Although the changes in fruit quality after grafting have been widely reported, the mechanisms involved in regulating fruit characteristics with different rootstocks are still unknown. Therefore, the aim of this investigation was to determine the effects of rootstock variation on growth, yield and quality of some watermelon hybrids. Also, to illuminate the importance of carefully selection of rootstock/scion combinations to ensure high quality grafted vegetable fruit.

2. Materials and methods

2.1 Experimental site

The experiments were conducted on watermelon (*Citrullus lanatus* L.) at an a private farm in Awlad Amr village, Qena city, Qena, Egypt located between 26° 10′ 0″ N, 32° 43′ 0″ E during the two consecutive spring-summer seasons of 2018 and 2019 respectively to Study the effect of three different genotypes used as rootstocks on plant growth performance, fruit yield and quality of three watermelon F_1 hybrids used as scion in a clay loam soil as presented in Table (1).

Table (1): The physical and chemical properties of the samples taken from experimental soil during the two cultivated seasons.

Characteristic	Value	Characteristic	Value
O.M. (%)	1.2	Cl	1.65
$CaCO_3$ (%)	2.35	Mg^{+2}	5.13
Sand (%)	38.3	Na^{+}	10.5
Silt (%)	21.8	K^{+}	0.23
Clay (%)	39.9	Available (ppm)	
Texture class	Clay loam	NH_4	48.0
pH	7.75	N	62.4
EC (dS/m)	1.55	P	9.2
Soluble ions (me/L)		K	356
CO_3	-	$SO4^{-2}$	11.45
HCO_3	8.45	Ca^{+2}	5.40

2.2 Experimental materials

2.2.1 Plant material

Watermelon, Aswan F_1, misr1 F_1 and Star hybrids were used as non-grafting judging elements. These hybrids are grown on a large scale in the commercial production of watermelons in Egypt, and Cobalt F_1, Ferro F_1 and New Star F_1 hybrids were used as a rootstock. Watermelon scion and rootstock seed sources are shown in Table (2).

2.2.2 Grafting method and experimental design

The seeds of the rootstocks were sown 10-15 days earlier than the seeds of the scions to ensure similar stem diameters at the grafting time due to the differences in growth vigor. In both cultivated seasons of 2018 and 2019 at 25 December and 10 January seeds of rootstock and scion were sown respectively in 130-cell styrophoam trays under greenhouse conditions in a private nursery of Qena city, Qena, Egypt. The trays were filled with soil mixture (peat moss, vermiculite and perlite mixes in 1:1:1 v/v/v). They were grafted on 15 January 2018 and 2019. Grafted plants were kept in a small tunnel under semi-controlled environmental conditions. Seedlings grew without light and with a >90% RH (Relative Humidity) for four days, then light was gradually increased, and relative humidity was decreased. The environmental conditions for germination were 24-28°C and 85-90% relative humidity. Tongue approach grafting method was the best grafting method for watermelon as reported by Hussien (2011) and was used in this study as described by Hassell *et al*. (2008). At the two true-leaf stage (10 February of 2018 and 2019), grafted plants were transplanted in rows 3.0 m wide and 5 m long, spaced 0.5 m apart at the open field. During the plant-growing period, furrow irrigation was used. Insecticide was applied to avoid crop damage by cabbage worms and aphids. Weeds were kept under control manually. The experiment was set up in a randomized completely block design (RCBD) with three replicates for each treatment.

Table (2): Watermelon scion and rootstock seed sources and origin country.

Rootstock	Hybrid Type	Importing Company	Origin
Cobalt F_1	*C. maxima* X *C. moschata*	Egypt Company	Netherlands
Ferro	*C. maxima* X *C. moschata*	Egypt Company	Netherlands
New Star	*C. maxima* X *C. moschata*	New Star Company	Serbia
Watermelon Hybrid			
Hybrid	Importing Company		Origin
Aswan F_1	Sakata Company		Japan
Misr1 F_1	Islamic Company		India
Star F_1	New Star Company		USA

2.2.3 Experimental treatments

Watermelon hybrid used in this study was grafted onto three genotype rootstocks as follow:

- Aswan F1 (control), Aswan F1\ Cobalt F1, Aswan F1\Ferro F1 and Aswan F1\ New Star.
- Misr1 F_1 (control), Misr1 F_1\ Cobalt F_1, Misr1 F_1\ Ferro F_1 and Misr1 F_1\ New Star.
- Star F_1 (control), Star F_1\ Cobalt F_1, Star F_1\ Ferro F_1 and Star F_1\ New Star.

2.2.4 Agricultural operations

Grafted seedlings were initially grown in a greenhouse and fertilized with 19:19:19 for N: P: K soluble fertilizers. During soil preparation a mixture of 1 m3 of poultry manure (2.5% N, 1.5% P_2O_5 and 2.1% K_2O) plus 5 kg ammonium nitrate (33.5% N), 20 kg calcium super phosphate (15.5% P_2O_5), 5 kg potassium sulfates (50% K_2O) and 1.5 kg magnesium sulphates were applied as basic fertilizers, for each 200 m2 of the trials. Two weeks after transplanting a fertigation program was started to complete the fertilization regimes to the levels of (120 kg N, 100 kg P_2O_5 and 100 kg K_2O /feddan) (feddan = 0.420 hectares = 1.037 acres). At flowering stage an additional doses of potassium sulfates was divided into three equal parts and applied as top dressing near the roots every 15 days, to reach level of 150 kg K_2O /feddan. Fruit thinning was carried out after three weeks from fruit setting, and the selected fruits were remarked, then all female flowers and escaped fruits were removed twice a week. Other cultivation practices were applied to all experiment area during both growing seasons according to the Egyptian Ministry of Agriculture recommendations for the spring-summer season.

2.2.5 Data Taken

Harvesting was carried out upon fruit maturity symptoms. All harvested fruits were weighted, then mean fruit weight /kg (FW) and total yield ton /feddan (FY) were calculated. Also, fruit length cm (FL) and fruit circumferences cm (FC) were measured. Tow medium fruits from each replicate were used to measure average fruit skin thickness (FST) and total soluble solids (TSS) in flesh as fruit quality indicator. As well as plant height m (PH) and number of branches per plant (BN/P) was determined at harvesting time.

2.2.6 Statistical analysis

Data were subjected to the statistical analysis of ANOVA, and the entries means were compared according to the least significant differences (LSD) at 5% levels, as reported by Gomez and Gomez (1984). All statistical analysis was performed with MCTAT computer software.

3. Results

Data displayed in Tables (3) and (4) shows the impact of grafting watermelon hybrid Star F_1, Misr 1 F_1 and Aswan F_1 on three original rootstocks *i.e*. Ferro F_1, New Star F_1 and Cobalt F_1 as well as direct seeded plants of watermelon (without grafting as a control) on plant height and number of branches per plant. The data clarify that grafting enhanced significantly plant height and branches number per plant compared to nongrafted plants as a control. Among the original rootstocks, it was obvious that rootstock Cobalt F_1 exceeded New Star F_1 and Ferro F_1 rootstocks for plant height, while, Ferro F_1 exceeded Cobalt F_1 and New Star F_1 rootstocks for plant height for branches number per plant.

Table (3): Effect of rootstock on plant height m of grafted watermelon in hybrids Star F_1, Misr 1 F_1 and Aswan F_1.

Scion / Rootstock	2018/2019				2019/2020			
	Star F_1	Misr 1 F_1	Aswan F_1	Means b	Star F_1	Misr 1 F_1	Aswan F_1	Means b
Ferro F_1	3.24	3.67	3.57	3.49	3.33	3.73	3.72	3.60
New Star F_1	3.31	3.38	3.38	3.36	3.30	3.70	3.59	3.53
Cobalt F_1	2.87	3.30	3.45	3.21	3.01	3.49	3.12	3.21
Check	1.66	2.76	2.13	2.18	1.83	2.26	2.84	2.31
Means a	2.77	3.28	3.13	---	2.87	3.30	3.31	---
LSD	a= 0.15 b= 0.17 ab=0.29				a= 0.24 b= 0.29 ab=0.31			

Table (4): Effect of rootstock on branches number per plant of grafted watermelon in hybrids Star F_1, Misr 1 F_1 and Aswan F_1.

Scion / Rootstock	2018/2019				2019/2020			
	Star F_1	Misr 1 F_1	Aswan F_1	Means b	Star F_1	Misr 1 F_1	Aswan F_1	Means b
Ferro F_1	9.0	6.4	8.6	8.0	9.6	7.0	8.9	8.5
New Star F_1	9.3	7.0	8.2	8.2	10.0	7.8	8.8	8.9
Cobalt F_1	9.2	8.6	8.4	8.7	10.0	9.4	9.3	9.9
Check	5.9	5.8	6.6	6.1	6.2	4.8	6.2	5.7
Means a	8.4	7.0	8.0	---	9.0	7.2	8.3	---
LSD	a=0.63 b=0.73 ab=1.26				a=0.58 b=0.67 ab=2.11			

Analysis of the results obtained from Tables (5, 6, 7 and 8) refers to the influence of grafting watermelon on average fruit weight kg, fruit length cm, fruit circumference cm and total fruit yield as ton per feddan. The results showed significantly differences in all grafted and non-grafted plants. Misr 1 F_1 hybrid recorded the best response to the fruit traits *i.e*., fruit weight kg, fruit length cm, fruit circumference cm and total fruit yield ton /feddan compared to the other hybrids. On the other hand, Cobalt F_1 rootstock was the best in combination with watermelon hybrids. Misr 1 F_1 /Cobalt F_1 gave the highest values of fruit traits kg followed by Aswan F_1 /Cobalt F_1 in both seasons.

Table (5): Effect of rootstock on fruit weight kg of grafted watermelon in hybrids Star F_1, Misr1 F_1 and Aswan F_1.

Scion / Rootstock	2018/2019				2019/2020			
	Star F_1	Misr 1 F_1	Aswan F_1	Means b	Star F_1	Misr 1 F_1	Aswan F_1	Means b
Ferro F_1	8.2	8.6	8.6	8.5	8.7	9.6	9.3	9.20
New Star F_1	9.0	9.8	8.8	9.2	9.0	9.4	9.5	9.3
Cobalt F_1	9.4	10.4	9.9	9.9	9.6	10.8	9.8	10.2
Check	7.6	8.0	7.7	7.8	8.3	8.4	7.4	8.0
Means a	8.6	9.2	8.8	---	8.9	9.6	9.0	---
LSD	a=0.22 b=0.25 ab= 0.21				a=0.12 b=0.14 ab=0.24			

Table (6): Effect of rootstock on fruit length cm of grafted watermelon in hybrids Star F_1, Misr 1 F_1 and Aswan F_1.

Scion / Rootstock	2018/2019				2019/2020			
	Star F_1	Misr 1 F_1	Aswan F_1	Means b	Star F_1	Misr 1 F_1	Aswan F_1	Means b
Ferro F_1	33.5	36.5	34.5	34.8	32.6	35.5	33.4	33.8
New Star F_1	34.8	37.3	35.2	35.8	33.9	36.7	34.6	35.1
Cobalt F_1	35.7	39.0	36.9	37.2	34.4	38.7	36.0	36.4
Check	31.6	33.4	32.5	32.5	30.4	33.8	31.8	32.0
Means a	33.9	36.6	34.7	---	32.8	36.2	33.9	---
LSD	a=1.31 b=1.51 ab=2.61				a=1.81 b=2.088 ab=3.62			

Table (7): Effect of rootstock on fruit circumference cm of grafted watermelon in hybrids Star F_1, Misr 1 F_1 and Aswan F_1.

Scion / Rootstock	2018/2019				2019/2020			
	Star F_1	Misr 1 F_1	Aswan F_1	Means b	Star F_1	Misr 1 F_1	Aswan F_1	Means b
Ferro F_1	32.5	35.4	34.4	34.6	32.1	37.2	36.4	35.2
New Star F_1	34.5	38.2	34.8	35.9	33.2	39.4	37.0	36.5
Cobalt F_1	36.7	37.2	36.7	36.9	36.6	39.7	38.8	38.4
Check	30.4	31.3	32.4	31.4	29.9	32.4	31.8	31.3
Means a	33.5	35.5	34.6	----	32.8	37.2	36.0	----
LSD	a=1.31 b=1.51 ab=2.61				a=1.81 b=2.09 ab=3.62			

Table (8): Effect of rootstock on fruit yield ton/feddan circumference cm of grafted watermelon in hybrids Star F_1, Misr 1 F_1 and Aswan F_1.

Scion / Rootstock	2018/2019				2019/2020			
	Star F_1	Misr 1 F_1	Aswan F_1	Means b	Star F_1	Misr 1 F_1	Aswan F_1	Means b
Ferro F_1	50.0	52.6	49.2	50.6	52.3	54.8	52.0	53
New Star F_1	55.8	57.6	53.3	55.6	57.5	58.6	53.9	56.7
Cobalt F_1	56.5	58.02	55.7	56.7	57.9	60.9	55.5	58.1
Check	30.2	38.3	31.77	33.4	33.3	38.0	32.6	34.7
Means a	48.1	51.6	47.5	---	50.2	53.1	48.5	---
LSD	a=2.17 b=2.51 ab=4.35				a=4.25 b=4.91 ab= 3.61			

Meanwhile, hybrid plants which grafted onto Ferro F_1 scored the lowest response for fruit traits to scion /rootstock combination in both seasons. Data presented in Tables 9 and 10 illustrated that grafted hybrids of watermelon plants onto Ferro F1, New Star F1 and Cobalt F1 rootstocks had not significant affect fruit skin thickness in both seasons, but it was significantly affects on fruit TSS. the greatest values of TSS were recorded by watermelon grafting onto Cobalt F_1 rootstock in both seasons. While grafted plants onto Ferro F_1 gave the lowest values in both seasons. Furthermore, own rooted plants nearly occupied intermediate rank among different treatments in both seasons. Grafting Star F_1 onto Cobalt F_1 followed by Aswan F_1 onto Cobalt F_1 scored the heights values of watermelon fruit TSS in both seasons. While, Misr 1 F_1 onto Ferro F_1 recorded the lowest values of watermelon fruit TSS in both seasons.

Table (9): Effect of rootstock on fruit skin thickness of grafted watermelon in hybrids Star F_1, Misr 1 F_1 and Aswan F_1.

Scion / Rootstock	2018/2019				2019/2020			
	Star F_1	Misr 1 F_1	Aswan F_1	Means b	Star F_1	Misr 1 F_1	Aswan F_1	Means b
Ferro F_1	1.51	1.70	1.6	1.60	1.51	1.65	1.64	1.60
New Star F_1	1.49	1.67	1.62	1.60	1.50	1.59	1.64	1.57
Cobalt F_1	1.42	1.58	1.70	1.57	1.50	1.61	1.58	1.54
Check	1.35	1.49	1.28	1.37	1.33	1.50	1.26	1.37
Means a	1.44	1.61	1.55	---	1.46	1.59	1.51	---
LSD	a=ns b=ns ab=ns				a=ns b=ns ab=ns			

Table (10): Effect of rootstock on fruit TSS of grafted watermelon in hybrids Star F_1, Misr 1 F_1 and Aswan F_1.

Scion / Rootstock	2018/2019				2019/2020			
	Star F_1	Misr 1 F_1	Aswan F_1	Means b	Star F_1	Misr 1 F_1	Aswan F_1	Means b
Ferro F_1	9.83	9.56	9.78	9.72	10.2	9.70	9.83	9.72
New Star F_1	9.94	9.70	9.84	9.85	10.1	9.51	9.78	9.78
Cobalt F_1	10.38	9.67	9.93	9.96	10.4	9.22	10.05	9.90
Check	9.61	8.78	9.23	9.20	9.39	9.55	9.39	9.44
Means a	9.94	9.41	9.70	---	10.00	9.36	9.76	---
LSD	a=ns b=0.14 ab= 0.88				a=ns b=0.19 ab= 0.50			

4. Discussion

Growth attributes results were presented in Tables (3) and (4). The result of the study revealed that among growth parameters length of the main vine and number of branches per plant was significantly higher in grafted plants than that of non-grafted plants. Vigorous plant growth in grafted watermelon was observed in several studies (Boughalleb *et al*., 2008; Mohamed *et al*., 2012; Tarchoun *et al*., 2005; Yetisir *et al*., 2007). Promoted watermelon plant growth in the grafted plants can be explained by the interaction of some or all of the following phenomena: increased water and plant nutrient uptake (Pulgar *et al*., 2000), due to stronger and more extensive root growth of the rootstock (bottle gourd), augmented endogenous hormone production (Zijlstra *et al*., 1994), enhanced scion vigor (Leoni *et al*., 1990). Data of fruit weight are presented in Table (5) revealed that, fruit weight kg was significantly influenced by grafting. Our result agrees with those of Ozlem *et al.* (2007) and El-sayed *et al*. (2014). Also, Petropoulos *et al.* (2012) stated that mean fruit weight at harvest was higher in grafted watermelon plants than in self-rooted others. Our results of fruit quality were in accordance with those of Salam *et al*. (2002) which reinforced a marked increase in watermelon fruit TSS content when grafted onto bottle gourd. Yetisir *et al*. (2003) found that the soluble solids contents were affected significantly by the rootstock. Ozlem *et al.* (2007) stated that fruit rind thickness did not affected by grafting watermelon on pumpkin and bottle gourd rootstocks under either open field or low tunnel growing conditions whoever, fruit total soluble content (TSS) was decreased by grafting compared to non-grafting not for all rootstocks under open field conditions but under low tunnels TSS did not impacted by grafting or non-grafting. On muskmelon, findings by Yi-Fei, *et al*. (2011) revealed that grafting muskmelon plants enhanced the net photosynthesis rate, carbohydrates contents and translocation of sugars in muskmelon leaves. Otherwise, Miguel *et al*. (2004) did not find any difference in TSS of watermelon fruit from grafted and non- grafted others. Meanwhile, Turhan *et al*. (2012) found that grafting watermelon on three squash hybrid rootstocks led to decrease total sugars and total soluble solids but increase rind thickness of fruits than non- grafting. Also, Petropoulos *et al.* (2012) stated that in grafted watermelon, fruit sugar content varied with scion-rootstock combination. The performance of grafting in total fruit yield increasing as shown in Table (8) during both seasons may be due to the strong vegetative growth and higher average fruit weight comparing to non-grafted plants. In this concern, many authors proved that grafting affected fruit yield of watermelon (Alan *et al.*, 2007; Besri, 2008; Rouphael *et al.*, 2008). Islam *et al.* (2013) state that fruit yield of grafted watermelon was increased one and half times more than non-grafted plants. Sakata *et al.* (2005) reported that yield and fruit weight of grafted watermelons onto Shintosa rootstock were higher than those with other rootstocks. On the other hand, Yetisir *et al.* (2003) compared the effects of different rootstocks [squash interspecific hybrids (*Cucurbita moschata* × *Cucurbita maxima*) and bottle gourd (*Lagenaria siceraria*)] on fruit yield of watermelon. The results cleared the grafted plants onto bottle gourd produced 27–106% greater yield over control plants, but the *Cucurbita* sp. rootstock decreased yield by 127–240%. Colla *et al*. (2006) and Yetisir *et al*. (2003) reported that the lowest yield recorded in own rooted watermelons associated with a decrease in both average fruit weight and the number of fruits per plant compared to grafted plants. Further, grafting can increase yield since grafted plants are resistant to soil-borne disease, have strong root systems, and increased photosynthesis (Qi *et al.*, 2006; Wu *et al.*, 2006; Xu *et al.*, 2005).

5. Conclusion

According to the obtained results in this study, watermelon grafting onto Cobalt F_1 rootstock the best treatment that could be recommended to obtain the highest yield and improve fruit quality of watermelon in Qena province, Egypt and other regions with similar agroclimatic conditions. Also, these results showed that using specific rootstock to graft watermelon influences growth, yield and, sometimes, fruit quality. Moreover, these results may be raising the awareness of Egyptian growers to use the grafted watermelons.

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