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Effects of Grafting on Nutrient Element Content and Yield in Watermelon

Karpuzda Aşılamanın Besin Element İçeriği ve Verim Üzerine Etkisi

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Key Words:

Citrullus lanatus, Rootstock, Scion, Nutrient element; Yield

ABSTRACT

This study was conducted to determine the effects of grafting and rootstock-scion combinations on the yield and nutrient content for both the leaves and fruit of watermelons. Two watermelon (*Citrillus lanatus (Thunb.) Matsum and Nakai*) varieties Crisby and Crimstar were grafted on to Ferro and RS 841, and the commercial hybrids of *Cucurbita maxima x Cucurbita moschata*. Non-grafted plants were used as controls. In the grafted plants the content of K, Mg, Ca, Fe, Cu, Zn and Mn in the leaves and N in fruits significantly increased when compared to the control. A significant effect was observed in the rootstocks for the Fe, Cu, Zn content in the leaves and the N, P, Ca, Cu and Zn content in the fruit. The K and Fe content in the leaf and the Fe, Cu, Zn and dry matter content in the fruit were also found to be significant between the varieties. Grafting and rootstock-scion combinations affect fruit yield. The Crimstar/Ferro combination had the highest yield. Also, in the grafted plants, the dry matter content of the fruits had a significant positive correlation with the Ca and Mg content of the leaves.

Anahtar Sözcükler:

Citrullus lanatus, Anaç, Kalem, Besin Elementi, Verim

ÖZET

Bu çalışma, aşılı fide kullanımının ve farklı anaç-kalem kombinasyonlarının, karpuz bitkisinin yaprak -meyve besin element içeriklerine ve verimine etkilerinin belirlenmesi amacıyla yürütülmüştür. Crisby ve Crimstar çeşitlerinin, Ferro ve RS 841 (*Cucurbita maxima x Cucurbita moschata*) ticari hibrit anaçlarına aşılı fideleri ile aşısız (kontrol) fideleri kullanılmıştır. Aşılı bitkilerin, yapraklarında K, Mg, Ca, Fe, Cu, Zn, Mn içerikleri; meyvede N içerikleri kontrole (aşısız olanlara) göre önemli düzeyde artmıştır. Anaçların, yaprak Fe, Cu, Zn; meyve N, P, Ca, Cu, Zn içeriklerine önemli etkisi gözlenmiştir. Yaprakların K ve Fe içerikleri ile meyvelerin Fe, Cu, Zn ve kuru madde içerikleri, çeşitler arasında önemli farklılıklar göstermiştir. Aşılama ve anaç-kalem kombinasyonlarının verim üzerine önemli etkisi olmuştur. Ferro anacına aşılı Crimstar çeşidi ile en yüksek verim elde edilmiştir. Aşılı bitkilerde meyvenin kuru madde içeriği ile yaprakların Ca ve Mg içerikleri arasında önemli pozitif korelasyon belirlenmiştir.

INTRODUCTION

Research on vegetable grafting first began in Japan in the late 1920s on watermelons with respect to scope with soil pathogens and has been much studied since then (Lee, 1994; Lee et al., 2010). In the last few decades, however, vegetable grafting has also been performed to enhance the tolerance of adverse soil conditions such as salinity, excessive moisture and low soil temperature, more efficient uptake and use of water and plant nutrients, an increase in plant strength, an increase in the economic harvesting period and a corresponding increase in yield, and a reduction in the use of agricultural chemicals (Santa Cruz et al., 2002; Yetişir et al., 2004; Abdelmageed and Gruda 2009). Grafting is environmentally friendly that it reduces the use of chemicals in agriculture (Rivard and Louws 2008).

The performance of grafted plants depends on the compatibility between the rootstock and scion, environmental conditions, and production methods. According to many studies, the scion-rootstock combination may affect plant growth and development, as well as fruit quality such as sugar content, carotenoid content, the chemical composition of the fruit, flavor, and aroma (Bletsos and Passam 2010; Bekhradi et al., 2011; Gisbert et al., 2011; Khah 2011). This effect is mainly attributed to a rootstock-scion interaction, which influences various plant physiological processes such as the nutrient and water uptake and translocation, hormone synthesis, photosynthesis, and other metabolic processes (Petropoulos et al., 2012). In order to ensure the best use of the rootstocks, suitable rootstock-scion combinations must be determined for specific climatic and geographic conditions. The select of rootstock is of great importance for successful grafting, as plant nutrition and yield, and fruit quality, may be adversely affected (Hartmann and Schwarz 2009). The relationship between the rootstock-scion may help to identify the tolerance of the root system to soils, which have a deficiency or an excess of specific nutrition elements in the formation of fertilization programs (Ruiz et al., 1997).

The amount of nutrient elements which plants absorb from the soil are under the control of various factors. These may be basically classified under the headings of soil, environment, and plant factors. Soil characteristics such as pH, lime, organic matter and the nutrition element contents, along with factors such as rainfall, temperature, and cultural practices, affect the uptake of nutrient elements by the plants. Plant characteristics are one of the basic criteria in determining the effectiveness of these factors. For example, the age of the plant, its stage of development, and the variety and the structure of its root system to a certain extent all affect to the amount of nutrients which the plant can absorb from the soil (Erdal et al., 2005).

Plant nutrition is of great importance in attaining a high level of yield in watermelons (Barneix and Causin 1996). As much as the adequacy of the plant nutrient materials in the soil, the ability to uptake them up is very important. Andrade Junior et al. (2006) reported that the amount of nitrogen applied by fertigation could increase the marketable yield; Yadav et al. (1989) reported that the amount of nitrogen increased the yield, the number of renewable fruit, and the main stem length; while Miller (2002) found that the application of excess amounts of nitrogen increased the plant development in watermelons, but could reduce yield.

Turkey is one of the world's most important watermelon-producing countries after China, with 3.9 million tonnes on a 158.520 ha of land (FAOSTAT 2014). The region of Odemis is one of the most important in Turkey for watermelon production. The objective of this research was to evaluate the influence of grafting and rootstock-scion combinations on the content of nutrient elements in both the leaves and fruit of watermelon plants, and on the yield in commercial watermelon regions.

MATERIAL and METHODS

The study was carried out in the experimental fields of the Odemis Vocational School, at the Ege University, in Izmir (38°16 'N; 27°59 'E; 123 m above sea level). The climatic conditions during the experiment are given in Table 1. The watermelon varieties (Crispy and Crimstar),which are widely grown in the area, were grafted onto 'Ferro' and 'RS-841', and the commercial hybrids of the *Cucurbita maxima x Cucurbita moschata*. Non-grafted plants were used as a control. Both the grafted and non-grafted control plants were obtained from a private supplier.

Table 1. Meteorological data for the experimental year

	May	June	July	August
Average Temperature (°C)	21.5	26.9	29.3	28.6
Maximum Temperature (°C)	36.6	43.5	44.6	41.8
MinimumTemperature (°C)	8.3	14.0	14.3	16.2
Relative Humidity (%)	60.8	49.3	42.1	48.3
Total Rainfall (mm)	31.7	7	-	-

The experimental designs were randomized complete blocks consisting of three treatments. One treatment had non-grafted control plants, one treatment had Ferro rootstock plants, and the other had RS 841 rootstock plants. Each treatment was replicated three times, with 15 plants in each replicate. The plants were planted into the soil on 18 May at two meter intervals, with two meters between rows, and a density of 2500 plants/ha. All the plots were fertilized equally with 15:15:15 at the time of planting, and with potassium nitrate (KNO_3) at the time of the first irrigation as 140 N kg ha^{-1}, 120 P_2O_5 kg ha^{-1} and 200 K_2O kg ha^{-1} (IFA 1992). The furrow irrigation was applied as required, and other cultivation practices were conducted. The harvests were carried out three times from the end of the July until the end of the August.

Soil samples (0–30 cm and 30-60 cm depth) were taken and pH (Jackson, 1967), total soluble salt (Anonymous, 1951), CaCO3 (Kacar, 1995), organic matter content (Reuterberg and Kremkurs, 1951) and texture (Bouyoucos, 1962) were determined. Macro- and micronutrients contents of the soils were also analysed. Total N was determined according to Bremner (1965), and the available K+, Ca++ and Na+

were determined after extracting with 1 N NH4OAc by flame photometer and Mg++ by Atomic Absorption Spectrometer (AAS) (Jackson, 1967; Atalay et al., 1986). Available P was measured by colorimeter after extracting with distilled water (Bingham, 1949) and available Fe, Mn, Zn and Cu were measured with 0.05 M DTPA + TEA extraction by AAS (Lindsay and Norvell, 1978).

The physical and chemical characteristics of the soil of the experimental plots, which were Typic Xerofluvent, are set out in Table 2. The soil was a loamy sand, neutral pH, without salt problems and low in organic matter, available P, K. Total N, available, Mg, Fe, Zn, Mn, and Cu values were sufficient. Calcium content was medium.

Table 2. Soil Characteristics of the Experimental Area.

Characteristics		**(0-30cm)**	**(30-60cm)**
pH		7.15	6.86
Salt	(%)	0.03	0.03
Organic Matter	(%)	0.57	0.77
$CaCO_3$	(%)	0.56	0.64
Sand	(%)	84.92	76.92
Lime	(%)	2.72	2.72
Silt	(%)	12.36	20.36
Texture		Loamy sand	Loamy sand
Total N	(%)	0.12	0.13
Available P	(mg kg^{-1})	0.22	0.25
Available K	(mg kg^{-1})	71	70
Available Ca	(mg kg^{-1})	1500	1486
Available Mg	(mg kg^{-1})	485	480
Available Fe	(mg kg^{-1})	4.92	4.8
Available Mn	(mg kg^{-1})	2.81	2.15
Available Zn	(mg kg^{-1})	3.22	2.85
Available Cu	(mg kg^{-1})	0.49	0.52

In order to determine the nutritional status of the plants, the young mature leaves were taken as samples in the middle of the development period (Reuter and Robinson 1986). For the fruit sampling, three fully ripe fruits were taken from each plot. After washing the leaf samples clean in both normal and distilled water, they were dried at 65°C in order to prepare them for analysis (Kacar, 1984). About 100g of fresh material was taken from the fruit samples to determine the amount of dry material, and approximately 300-400 g was taken and weighed for the determination of the nutritional element content. The total N was determined in the prepared plant samples by the modified Kjeldahl method (Bremner, 1965; Baker and Thompson 1992). In the plant extracts which obtained after wet digestion with mixed acid (1 part HClO4 + 4 parts HNO3), P were determined colorimetrically by the vanadomolybdophosphoric yellow color method (Lott et al., 1956), K, Ca and Na in a flame photometer, and Mg, Fe, Mn, Zn, and Cu in an atomic absorption spectrophotometer (AAS) (Slawin, 1968; Kacar, 1984; Hanlon, 1992). The known amounts of ground leaf samples and fresh fruit samples were heated in a drying oven which was heated in stages to 105°C until their weights stabilized, and the percentage of dry matter content (DMC) was determined through calculation.

The analysis of the variance was performed using the SAS statistical program, and the significant differences between treatments were compared using an orthogonal statistical design.

RESULT and DISCUSSION

The effect of the grafting on the nutrient element content of the leaves is given in Table 3. This shows that no significant effect was observed on the N and P content of the leaves in the grafted and non-grafted control plants.

The grafting significantly affected the K content of the leaves ($p<0.01$). The control plants had the lowest K content (3.0%) when compared to the grafted plants. No differences were found between the rootstocks for the K content (Table 3). The amounts of K in the leaves showed a significant difference between the varieties ($p<0.01$) it was higher in the Crimstar than in the other variety. Ruiz et al. (1997) also reported that grafting had a significant effect on the K content of melon leaves, but unlike our findings, they did not find any effect invariety. In addition, the enhancement of the K uptake due to grafting has also been reported by some authors, specifically Leonardi and Giuffrida (2006) for eggplants, Qi et al. (2006) for melon, and Zhu et al. (2008) for cucumber.

Significant differences were found between the control and the grafted plants in leaf content of the Ca and Mg ($p<0.01$, $p<0.05$), with the leaf Ca and Mg content of the grafted plants being higher than in the control plants. Non-significant differences in Ca and Mg contents were found between rootstocks (Table 3). There was no significant effect in variety on the leaf Ca and Mg content. Ruiz et al. (1997), in a study carried out on melons, found no effect of grafting or variety on the leaf Ca and Mg content. Similarly to the results in the present study, Sun et al. (2010) found that the K, Ca and Mg content of watermelon leaves was higher in grafted plants than in the non-grafted ones. Savvas et al. (2010) suggested that the uptake and/or utilization efficiency of macronutrients by plants may be enhanced by grafting onto some rootstocks. This is ascribed mainly to the root characteristics of these rootstocks, which are more vigorous than those of the highly productive cultivated varieties.

Table 3. Effects of grafting on nutrient element content in watermelon leaves.

	N (%)			P (%)		
Treatments	Crispy	Crimstar	Mean	Crispy	Crimstar	Mean
Control	3.1	3.7	3.4	0.44	0.39	0.42
Ferro	3.2	3.5	3.4	0.34	0.52	0.43
RS 841	3.4	3.5	3.5	0.53	0.45	0.49
Mean	3.2	3.6		0.43	0.46	
T:n.s. V:n.s. T*V:n.s.				T: n.s. V:n.s T*V:n.s.		
	K (%)			**Ca (%)**		
Control	2.8	3.1	3.0	1.47	1.50	1.48
Ferro	3.7	4.9	4.3	1.80	2.30	2.05
RS 841	3.9	5.0	4.5	1.97	2.10	2.03
Mean	3.5	4.3		1.74	1.97	
T:p<0.01 V p<0.01 T*V: n.s.				T:p<0.01 V:n.s. T*V:n.s.		
	Mg (%)			**Fe (mg kg^{-1})**		
Control	0.36	0.36	0.36	34.00	29.50	31.75
Ferro	0.41	0.44	0.42	62.67	63.00	62.83
RS 841	0.44	0.43	0.44	107.00	91.00	99.00
Mean	0.40	0.41		67.89	61.17	
T: p<0.05 V:n.s. T*V:n.s.				T: p<0.01 V: p<0.05 T*V:n.s.		
	Cu (mg kg^{-1})			**Zn (mg kg^{-1})**		
Control	6.80	7.97	7.38	14.33	13.00	13.67
Ferro	8.70	9.90	9.30	19.50	22.00	20.75
RS 841	7.57	7.47	7.52	13.50	17.50	15.50
Mean	7.69	8.44		15.78	17.50	
T: p<0.05 V: n.s. T*V:n.s.				T: p<0.01 V:n.s. T*V:n.s.		
	Mn (mg kg^{-1})					
Control	6.20	6.50	6.35			
Ferro	9.10	7.47	8.28			
RS 841	8.83	8.13	8.48			
Mean	8.04	7.37				
T: p<0.01 V: n.s. T*V:n.s.						

T: Treatment. V:Variety. T*V: Treatment*variety. n.s.: non significant.

The leaf Fe content affected by treatments (p<0.01) and the control plants had the lowest amounts of Fe with 31.75 mg kg^{-1} (Table 3). Also, there was a significant difference between the rootstocks, with leaf Fe values higher for the RS 841 (99.00 mg kg^{-1}) than the Ferro rootstock. The amount of Fe in the leaves showed a significant difference between the varieties (p<0.05): it was higher in the Crisby than in the other variety. It has been stated that the differences between rootstocks with regardb to the take up of Fe and Cu may stem from phytosiderophores, and the ac idifying compounds affecting the availability of these elements in the rhizosphere (Mench and Farques 1994).

The copper, Zn and Mn content of leaves varied significantly between treatments (Cu: p<0.05, Zn, Mn: p<0.01) (Table 3). The leaf Zn and Mn content was found to be significantly higher in the grafted plants than in the controls. Also, the Cu and Zn content of the leaves showed a significant difference between the rootstocks: the Ferro rootstock had the highest average values of 9.30 and 20.75 mg kg^{-1} respectively. The leaf Mn content did not vary significantly between the rootstocks. According to the results of the statistical analysis, there was no difference between the varieties in terms of leaf Cu, Zn and Mn contents (Table 3). Ruiz et al. (1997) and Uygur and Yetişir (2009) reported that grafted plants developed better than non-grafted ones, and that there was a significant effect on the leaf mineral content of sweet melons and watermelons. Many studies revealed that some graft combinations were significantly more efficient in absorbing and indeed, transporting nutrients to the shoot, such as phosphorus, nitrogen, potassium, magnesium, calcium, iron, or other micronutrients, in comparisonwith non-grafted plants (Masuda and Gomi 1984; Pulgar et al. 2000; Salehi et al. 2010).

The interactions of the treatment*variety had no significant effect on the content of the macro and micro-nutrients examined in the leaves.

When the amounts of plant nutrient elements in the leaves were compared with the reference values given in Table 4, it was found that the N, P and K contents were adequate, and that K in the Crimstar grafted onto the Ferro and Crispy, and Crimstar grafted onto the RS 841 was above the level of adequacy.

Table 4. Reference Values of Plant Nutrient Elements for Mature Young Watermelon Leaves (leaf + stalk) in the Middle of the Development Period (Reuter and Robinson. 1986).

Element	Critical	Adequate
N (%)	2.0	2.5-4.5
P (%)	0.15	0.3-0.7
K (%)	2.0	2.5-3.7
Ca (%)		2.2-5.5
Mg (%)	0.15	0.4 -1.2
B (mg kg^{-1})	20	35-200
Cu (mg kg^{-1})	4	5-7
Fe (mg kg^{-1})		120-335
Mn (mg kg^{-1})	15	60-240
Zn (mg kg^{-1})	17	20-60

The amount of Ca in the leaves was found to be adequate in the Crimstar grafted onto the Ferro, but inadequate in the others. The Magnesium was inadequate in the control plants, while the grafted plants were found to be closer to the lower limits of adequacy. The amount of Cu in the leaves was adequate; Fe and Mn were inadequate; zinc was adequate in the Crimstar grafted onto Ferro, and the others were at an inadequate level.

The DMC and content of the plant nutrient elements for the watermelon fruits are shown in Table 5. The amount of DMC in the fruit showed significant differences between both treatments and varieties ($p<0.05$). There was a reduction in the amount of DMC in the grafted plants in comparison to the control group. In addition, the DMC content of the Crimstar with 7.9%, was significantly higher than that of the Crispy ($p<0.05$). Turhan et al. (2012) and Kappel et al. (2013) also stated that the fruit DMC content of the non-grafted plants was significantly higher than in the grafted plants. On the contrary, Proietti et al. (2008) found no difference in the DMC content between the grafted and non-grafted plants. The fruit DMC content is a possible fruit quality characteristic for watermelon. There are many conflicting reports on changes in fruit quality due to grafting. It has been reported that the differences in these results may be attributable in part to the different production methods and environments, the type of rootstock/scion combination used, and the harvest date (Davis et al., 2008; Rouphael et al., 2010).

The nitrogen content of the watermelon fruit was significantly affected by the grafting ($p<0.01$). When the average N values of the fruit were considered, it was found that the amount of fruit N in the control plants was lower than that of the grafted plants (Table 5). There was a significant difference between the rootstocks in terms of the fruit N content, with the N content of fruit grafted onto Ferro rootstock with 2.5% was higher than those of the RS 841 rootstock (2.1%).

The effects on the fruit P content of the treatments ($p<0.01$) and treatment*variety interaction ($p<0.05$) were found to be statistically significant. Also, although an effect of the varieties on the amounts of fruit P could not be determined, the effect of the rootstock was significant. It was found that fruits of the plants grafted onto the Ferro rootstock had a higher P content. The Crimstar grafted on to Ferro had a significantly higher level of P in the fruit (0.51%) than the control plants (Table 5). Similarly, Ruiz et al. (1997) advised that the P concentration in grafted melon plants can be affected by both the scion and by the rootstock-scion interaction. Rauphael et al. (2008), concluded that the P concentration in the leaves and stem of cucumber plants was affected significantly by the grafting combination. Also, Ruiz et al. (1996) reported that rootstocks could be responsible for an improvement in the various morphological and physiological characteristics by increasing the P absorption from the soil and its transportation into the plant. On the other hand, Tokgöz et al. (2015) reported that the amount of watermelon fruit P was unaffected or minimal by grafting.

The amount of K and Mg in the watermelon fruit did not show a significant difference between grafting treatments and varieties. Contrarily to the our results, Tokgöz et al. (2015) indicated that grafting increased the amounts of K and Mg in the watermelon fruits.

The calcium content varied significantly according to treatments ($p<0.05$). There was a significant reduction in the plants grafted onto the RS 841 rootstock. No difference was observed in the Ca content in either the control plants or those grafted onto the Ferro rootstock. Various other researchers have reported that grafting affects the uptake and transport of N, P Mg and Ca. The improved uptake of the nutrient elements in the grafted seedlings increases the photosynthesis; especially under optimum development conditions, which is reflected in the improvements in both product yield and quality (Ikeda et al. 1986; Ruiz et al. 1997; Pulgar et al. 2000; Rivero et al. 2003; Hu et al. 2006; Zhu et al. 2006).

The fruit Fe, Cu, and Zn content was significantly affected by the treatments, variety, and the interaction of the treatment*variety (Table 5). The fruit of the control plants was found to have the highest Fe, Cu and Zn values, and these levels were significantly reduced in the grafted plants. There was no significant difference in the Fe content between the rootstocks, but a significant difference was found in the Cu and Zn content. In the plants grafted onto the RS 841, the Cu and Zn levels were higher than in the others. Comparing varieties, it was found that the amount of Fe in the Crispy, and amounts of Cu and Zn in the Crimstar, were higher than in the others. In agreement with the results of this study, Edelstein et al (2007) reported that the levels of micro-elements such as Mn, Zn, Cu, and B, in grafted melon plants were lower than in the non-grafted ones. They reported that the lower trace element concentrations in fruits were ascribed mainly to differences in the characteristics of the root systems between the two plant types. Also, Rouphael et al (2008) stated that the uptake of micro-elements such as Cu in lettuces could be affected by grafting.

The Mn content of the watermelon fruit was found to be 2.5 times higher in the fruit of non-grafted control plants than in the grafted specimens, and this difference was statistically significant (p<0.01). No significant effect of rootstock or variety on the fruit Mn content was observed (Table 5).

Table 5. Effects of grafting on DMC and nutrient element content in watermelon fruits.

	DMC (%)			**Yield (kg ha^{-1})**		
Treatments	Crispy	Crimstar	Mean	Crispy	Crimstar	Mean
Control	7.6	9.1	8.3	17220	14410	15820
Ferro	5.9	7.3	6.6	32690	36050	34370
RS 841	7.7	7.4	7.5	33900	33620	33760
Mean	7.0	7.9		27940	28030	
T: p<0.05 V: p<0.05 T*V:n.s.				T:p<0.01 V:n.s. T*V:p<0.01		
	N (%)			**P (%)**		
Control	1.9	1.6	1.8	0.18	0.15	0.17
Ferro	2.4	2.7	2.5	0.39	0.51	0.45
RS 841	2.2	1.9	2.1	0.16	0.20	0.18
Mean	2.1	2.1		0.25	0.29	
T: p<0.01 V:n.s. T*V:n.s.				T:p<0.01 V:n.s. T*V: p<0.05		
	K (%)			**Ca (%)**		
Control	1.9	1.3	1.6	7.20	6.13	6.67
Ferro	2.0	2.3	2.2	6.47	6.83	6.65
RS 841	1.7	2.0	1.9	5.33	5.67	5.50
Mean	1.9	1.9		6.33	6.21	
T: n.s. V:n.s. T*V:n.s.				T: p<0.05 V:n.s. T*V:n.s.		
	Mg (mg kg^{-1})			**Fe (mg kg^{-1})**		
Control	1.17	0.93	1.05	644	306	475
Ferro	1.13	0.93	1.03	269	203	236
RS 841	1.17	1.07	1.13	235	183	209
Mean	1.16	0.98		383	231	
T: n.s. V: n.s. T*V:n.s.				T: p<0.01 V: p<0.01 T*V: p<0.05		
	Cu (mg kg^{-1})			**Zn (mg kg^{-1})**		
Control	7.0	7.0	7.0	15.0	17.0	16.0
Ferro	3.5	3.5	3.5	6.0	5.7	5.8
RS 841	3.5	6.5	5.0	6.7	14.0	10.3
Mean	4.7	5.5		9.2	12.2	
T: p<0.01 V: p<0.01 T*V: p<0.01				T: p<0.01 V: p<0.01 T*V: p<0.01		
	Mn (mg kg^{-1})					
Control	51.7	53.5	52.6			
Ferro	25.0	20.3	22.7			
RS 841	25.0	23.0	22.7			
Mean	33.9	32.3				
T: p<0.01 V:n.s. T*V:n.s.						

T: Treatment. V:Variety. T*V: Treatment*variety. n.s.: non significant.

The treatment and treatment*variety interaction had a significant effect on the watermelon yield (p<0.01) (Table 5). The yield was higher in the grafted plants than in the controls. The highest yield (36050 kg/ha) was found in the Crimstar grafted onto the Ferro. Similarly, various studies (Nielsen and Kappel 1996; Ruiz et al 1997) have reported that rootstocks had the effect of increasing production in grafted plants. It is thought that the increased production in grafted plants is related to the resistance to soil pathogens, tolerance to salinity and low temperatures in the root area, and increases in the uptake of water and plant nutrient (Kato and Lou 1989; Zekri and Parsons 1992; Lee, 1994). However, these positive effects of grafting were influenced by the different rootstocks. In general, the commercial hybrid rootstocks provided a more vigorous plant, and an increase in the yield, but the bottle gourd rootstock, and the *Cucurbita sp*. rootstock caused both weaker plant growth and a lower yield (Davis et al., 2008).

Also, significant correlations were found between the nutrient element contents in the experiment. In the grafted plants, the DMC in the fruit had significant positive correlations with the Ca and Mg content (with correlation coefficients of 0.62 and 0.59 respectively) in the leaf (Figure 1). The results of this study have shown that grafting significantly increases both nutrient elements, except the N, P in the leaves, and the Mg, K content in the fruit. There was a difference between the rootstocks, Fe, Cu, Zn content in the leaf, and the N, P, Ca, Fe, Cu, Zn content in the fruit was altered by the rootstocks used. The copper and Zn content in the leaf, and the N, P, Ca, Fe content in the fruit were found to be higher in the Ferro rootstock than in the RS 84. The potassium content in the leaf and the Fe, Cu, Zn contents in the fruit were affected by the variety. Grafting significantly increases the yield of the watermelon in particular, and the highest yields and P content in the fruit were obtained with the Crimstar grafted onto the Ferro rootstock.

It can be concluded that grafting in watermelon plants affected the plant nutrient element content and yield. These effects were altered by the rootstock-scion combinations being used. Therefore, rootstock-scion combinations should be carefully selected for specific soil, climatic, and geographic conditions. The relationship between the rootstock-scion may help in identifying the tolerance of the root system to soils which have a deficiency or an excess of specific nutrition elements, in the creation of fertilization programs. An appropriate selection can help increase the yield in commercial watermelon fields.

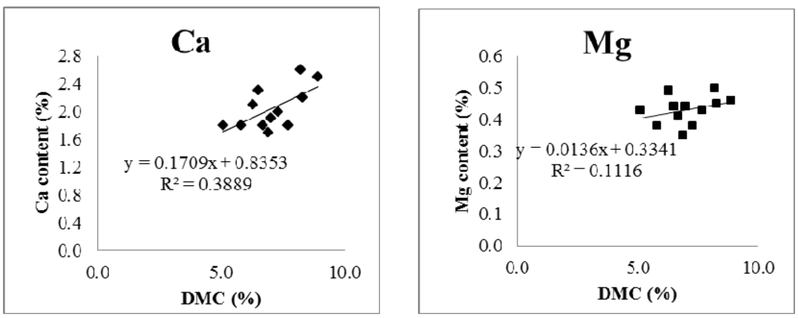

Figure 1. Regression equation between DMC in fruit and Ca-Mg content in leaf.

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