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IMPACT OF GRAFTING AND DEFICIT IRRIGATION ON YIELD OF MELON (*CUCUMIS MELO* L.)

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Abstract

An experiment was performed to evaluate the effects of grafting and deficit irrigation on yield of melon grown under different water stress conditions. The plant materials used in the study were Ünlü melon grafted on the rootstock of Ferro melon and ungrafted Ünlü melon species. Water was applied at the level of 80, 60 and 40% of the water applied to the full irrigation level (I_{100}=100%). Grafting significantly affected the fruit number of the plants. The fruit number in the ungrafted applications was higher than that in the grafted applications. Effects of grafting application and irrigation level on fruit weight was significant. The fruit weight in the ungrafted applications was higher than that in the grafted applications. Outcome indicated that there was no significant loss in yield, fruit number, or fruit weight of melons under application of 20% water deficit to the plants. Findings also revealed that the amount of irrigation water for melon cultivation can be safely reduced by 20% under Mediterranean climate conditions.

Introduction

Melon (*Cucumis melo* L.) is an important plant grown in temperate, subtropical and tropical regions across the world. Melon plant is a Cucurbitaceae plant such as cucumber, watermelon, and pumpkin (Rodríguez-Moreno *et al.* 2011). As with many cultivated plants, irrigation is an important input in melon cultivation. It is necessary to meet the demand of water needed by plants during the growing season through irrigation when it cannot be met by precipitation or natural methods. However, there is a rapid spread of soil-borne diseases and a decrease in yield depending on the amount of irrigation water and irrigation method applied to the melon (Nischwitz *et al.* 2004, Pivonia *et al.* 2004). In the case of scarcity irrigation conditions, the yield may decrease due to drought stress (Sharma *et al.* 2017, Wang *et al.* 2017, Ozbek and Kaman 2019).

Irregularities in precipitation regimes due to climate change and global warming, as well as the increasing use of freshwater resources, adversely affect freshwater resources that are already limited in semiarid and arid areas. This situation makes it necessary to reduce the amount of water used in agriculture. Grafting as a way to increase resistance to water deficiency stress in plants is being investigated with these aspects to provide the desired properties of the fruit and improve fruit quality (Silveira *et al.* 2020, Romero-Trigueros *et al.* 2020). Two plant parts with a similar organic structure are combined by different methods for growth, such as a single plant, owing to grafting. Currently, studies on grafted melons have been conducted, especially for reasons such as increasing resistance to soil origin diseases, ensuring yield and quality development, and increasing resistance to abiotic stresses (Olguín *et al.* 2020, Ulas *et al.* 2020, Ozbahce *et al.* 2021, Yavuz 2021). Thus, an attempt was taken on the yield responses of ungrafted and grafted Kırkağaç melon species grafted on Ferro melon rootstock under different restricted irrigation regimes.

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Materials and Methods

The research was carried out at the experimental field of Batı Akdeniz Agricultural Research Institute in Antalya Province, Turkey, in 2018. The experimental area is located at 36° 52′ north latitude and 30° 50′ east longitude, and the average elevation above the sea is 15 m. Antalya Province, where the research was carried out, has a typical Mediterranean climate. The summer months are hot and dry, and the winters are warm and rainy. The research area is composed of clay-loamy and clay-loamy-silty soils with slightly alkaline properties without drainage or any problems (Table 1). Soil samples were analyzed according to the principles given by Bouyoucos (1951), Blake (1965) and Peterson and Calvin (1965), and texture, field capacity, wilting point, bulk density and electrical conductivity values were determined (Table 1). The ratio of organic matter and macro- and micronutrient element contents in the soil samples were determined according to the principles set by Kacar (1990) (Table 2). Irrigation water is water that is classified as C2S1 according to the US Riverside salinity laboratory classification system (USSL 1954) and is suitable for agricultural production (Table 3).

Table 1. Some physical and chemical properties of soils in the experimental area.

Depth	Texture	$CaCO_3$	EC	pH	Bulk density	Field capacity (FC)	Wilting point (WP)	Total available water (TAW)
(cm)		(%)	(dS/m)		(g cm^{-3})	(mm)	(mm)	(mm)
0-30	SiC	25.6	0.103	8.3	1.33	107.7	70.8	36.9
30-60	SiC	24.8	0.108	8.3	1.36	104.4	59.7	44.7
60-90	SiCL	23.7	0.156	8.4	1.41	77.4	48.0	29.4
				For 0- 90 cm total:		289.5	178.5	111.0

Table 2. The nutrient content of the experimental area.

Depth (cm)	Organic matter (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
0-20	1.7	6	254	3893	386	5.8	2.5	0.6	1.1
20-40	1.1	8	306	4200	363	6.3	3.0	0.7	1.3

Table 3. Physical and chemical properties of irrigation water in the experimental area.

Cations (me l^{-1})				Anions (me/l)				pH	EC (dS/m)
Na^+	K^+	Ca^{++}	Mg^{++}	$CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$		
0.49	0.05	4.23	1.85	0.0	5.03	0.53	1.06	7.3	0.56

The Kırkağaç melon species (*Cucumis melo* L.) was grafted onto Ferro melon rootstock, and the ungrafted Ünlü species were used as plant material. The seedlings were planted on the site on April 30, 2018, and the last harvest was made on July 19, 2018. The study involved eight treatments consisting of four different irrigation levels (100, 80, 60 and 40%) and two melon species (ungrafted Ünlü and Ünlü grafted on the Ferro rootstock) in a randomized block design with three-replications (Table 4). There were three rows of plants in each parcel and 15 plants in each row. The parcels were arranged such that the distance between the plant row was 1.5 m, and the distance on the plant row was 1 m. The length of the row was 15 m. In the drip irrigation system, the laterals had a diameter of 16 mm, and the drippers had a flow rate of 4 l/hr. Irrigation was carried out to complete the existing soil water to the field capacity when 30-40% of the available water was consumed in the I_{100} irrigation treatment. The soil water content was monitored by the gravimetric method in three layers at depths of 0-30, 30-60 and 60-90 cm from the soil surface in the study.

Table 4. Irrigation treatments.

Treatment	Description
I_{100}	When 30-40% of water was consumed total available water (TAW) in the soil, it was completed to the field capacity by irrigation (Full irrigation).
I_{80}	(80% of I_{100}): When compared to I_{100} treatment, I_{80} was 20% less water.
I_{60}	(60% of I_{100}): When compared to I_{100} treatment, I_{60} was 40% less water.
I_{40}	(40% of I_{100}): When compared to I_{100} treatment, I_{40} was 60% less water.

In the I_{100} treatments of grafted and ungrafted treatments, the soil moisture content was determined separately, and the irrigation water to be given was calculated before irrigation. The amount of irrigation water to be applied to the control treatment in each irrigation was calculated using the following equation.

$$I = \left(\frac{FC_{0-90} - CW_{0-90}}{100}\right) \times D \times P$$

Where, I Amount of irrigation water (mm), $FC_{0\text{-}90}$ = Field capacity in the 0-90 soil layer (volume percentage, %), $CW_{0\text{-}90}$ = Measured present irrigation soil water content in the 0-90 cm soil layer at the beginning of the irrigation (volume percentage, %), D = Depth of the soil layer (mm), P Wetted area ratio (%). The wetted area ratio (P) in the study; the wet strip width was measured at the beginning, middle and near the end of the manifold and at the beginning, middle and near the end of the laterals to a soil depth of 30 - 40 cm, and the average value was calculated by proportioning to the lateral intervals (P value, 50%, in other words, 0.5). The following water budget equation was used to calculate ET.

$$ET = I + P + C - Dp - R \pm \Delta S$$

Where, ET = Evapotranspiration (mm), I = Irrigation water (mm), P = Precipitation (mm), C = Capillary rise (mm), Dp = Deep seepage (mm), R = Surface runoff (mm), ΔS = Moisture changes in the soil profile (mm). Concerning the elements of the equation, the precipitation (P) values were provided from the meteorological station. The capillary rise (C) was considered to be zero as the underground water was too low. Since the drip irrigation method was used as the irrigation method and the dripper flow rate was set to be less than the infiltration rate (13.5 mm ha^{-1}) in the drip irrigation method, no surface flow occurred during irrigation. That is why the value of R was also considered zero. Because measured water was given, deep penetration (Dp) was considered zero. The ±ΔS was calculated by subtracting the soil water content value measured immediately after the last harvest from the soil water content value immediately before planting at the beginning of the season.

By ET, yield and irrigation water, WUE and IWUE for each irrigation regime was calculated using the following equations:

$$WUE = \frac{Y}{ET}$$

$$IWUE = \frac{Y}{I}$$

Where, WUE = Water use efficiency (kg m^{-3}), Y = Yield (kg ha^{-1}), ET = Plant evapotranspiration (m^3), IWUE = Irrigation water usage efficiency (kg m^{-3}), I Irrigation water applied during the season (m^3).

Ky, which is an indicator of the effect of water deficiency on plant yield, was calculated using the following equation proposed by Doorenbos and Kassam (1979):

$$\left[1 - \frac{Ya}{Ym}\right] = ky \times \left[1 - \frac{ETa}{ETm}\right]$$

Where, Ya = Actual yield (t ha^{-1}) which corresponds to the actual plant evapotranspiration in the environments where the plant is cultivated, Ym = Yield obtained through maximum evapotranspiration in the environments where no water shortage is experienced through the growth season (t ha^{-1}), Ky = Yield response factor which shows the decrease in the yield due to a unit decrease in the evapotranspiration, Eta = Actual evapotranspiration in environments where the plant is cultivated (mm), ETm = Maximum evapotranspiration in environments where the plant is exposed to no water deficit through the growing season of the plant (mm).

Seedlings were planted on the site on April 30, 2018, for the first year, and the last harvest was made on July 19, 2018. The duration between planting seedlings in the field and the last harvest was 81 days. The harvested fruits were counted and weighed, and their total weight was calculated. The single fruit weight was calculated by dividing the total harvested fruit weight by the number of harvested fruits. The number of fruits per plant was calculated by dividing the total number of fruits harvested by the number of plants harvested. The total yield in the harvested area was calculated. The total yield in the harvested area was calculated.

The experiment was established in three replicates form according to a randomized parcel design. To determine the differences between the yield, IWUE, WUE, fruit number and fruit weight components, data obtained from the treatments were subjected to analysis of variance (ANOVA), and data for the characteristics with statistically significant differences were grouped at the 5% significance level using the LSD test. ANOVA and LSD tests were performed using the Jump 10 program.

Results and Discussion

Evapotranspiration (ET) ranged between 190.5 and 226.7 mm in the grafted plants, while the ET ranged between 246.5 and 283.7 mm in the ungrafted plants (Table 5). The yield values of all grafted treatments were lower than the I_{100}, I_{80} and I_{60} levels of ungrafted treatments (Table 6), while there was no significant difference between the I_{100} and I_{80} levels of grafted treatments and the ungrafted I_{40} treatment. The yield was ranked as $I_{100} \geq I_{80} > I_{60} > I_{40}$ in the ungrafted treatments and $I_{100} \geq I_{80} > I_{60} > I_{40}$ in the grafted treatments, from highest to lowest. When IWUE was considered the I_{40} level in ungrafted plants was higher than all irrigation levels in grafted plants and ungrafted I_{100} and I_{80} levels (Table 6). The IWUE in grafted plants was significantly reduced compared to that in ungrafted plants. WUE of the grafted I_{100} and I_{80} treatments was lower than those of the ungrafted I_{100} and I_{80} treatments. In other words, WUE in grafted plants showed a significant decrease compared to ungrafted plants (Table 6).

Table 5. Evapotranspiration (ET, mm) calculated based on the soil-water budget equation.

Treatments		I (mm)	P (mm)	±ΔS (mm)	ET (mm)
Grafted	I_{100}	118.9	77.8	30.0	226.7
	I_{80}	100.4	77.8	35.0	213.2
	I_{60}	84.0	77.8	35.4	197.2
	I_{40}	67.5	77.8	45.2	190.5
Ungrafted	I_{100}	144.9	77.8	61.0	283.7
	I_{80}	122.8	77.8	70.0	270.6
	I_{60}	100.8	77.8	76.2	254.8
	I_{40}	78.7	77.8	90.0	246.5

I: irrigation water applied, P: precipitation, ΔS: change in soil water storage in the 0.90 m soil profile, ET: evapotranspiration.

Table 6. Grafting and irrigation performance indicators: fruit yield, irrigation water use efficiency (IWUE), water use efficiency (WUE), fruit number per plant and mean fruit weight.

Treatments		Yield (t/ha)	IWUE (kg m^{-3})	WUE (kg m^{-3})	Fruits number per plant	Mean fruit weight (g/ fruit)
Grafted	I_{100}	27.07^{c}	23.1^{d}	12.0^{bc}	1.1^{c}	3866.7^{ab}
	I_{80}	26.77^{c}	26.7^{d}	12.6^{abc}	1.1^{c}	3822.3^{ab}
	I_{60}	22.37^{d}	26.6^{d}	11.3^{c}	1.0^{c}	3280.0^{ab}
	I_{40}	15.77^{e}	23.3^{d}	8.3^{d}	1.0^{c}	2324.3^{c}
Ungrafted	I_{100}	40.30^{a}	27.8^{cd}	14.2^{a}	1.4^{a}	4308.7^{a}
	I_{80}	39.20^{ab}	31.9^{bc}	14.5^{a}	1.4^{a}	4155.3^{a}
	I_{60}	35.20^{b}	34.9^{ab}	13.8^{ab}	1.2^{b}	4198.3^{a}
	I_{40}	29.60^{c}	37.6^{a}	12.0^{bc}	1.2^{b}	3620.0^{ab}
$LSD_{0.05}$		4.3139	5.1195	2.0116	0.1649	798.14
CV (%)		8	10	12	5	12

Lowercase letters on the bars indicate the statistical significance among the treatments.

Yavuz (2021) found that similar to this study, grafting did not cause an increase in yield, and the highest yield was obtained in the ungrafted treatment without water stress. The maximum yield values obtained in the ungrafted treatments in this study were similar to the findings of Wang *et al.* (2017), Cabello *et al.* (2009) and Sharma *et al.* (2020). Similar to the results of this study, Yavuz (2021) obtained the highest IWUE value in melon from with the grafting and the highest water stress. However, the IWUE values obtained in the present study were partially higher than the IWUE values reported previously by different investigations (Sensoy *et al.* 2007, Cabello *et al.* 2009, Simsek and Comlekcioglu 2011, Yavuz *et al.* 2021). It should be noted that this might be due to the climate, plant species, irrigation management, etc. The WUE values obtained in the study were similar to the maximum WUE values reported by Yıldırım *et al.* (2009) and Yavuz *et al.* (2021).

A strong linear relationship ($R^2 = 0.93$) was found between amount of irrigation water (I, mm) and yield (t ha^{-1}) in ungrafted melon (Fig. 1). In a similar manner, the correlation between amount of irrigation water and yield was calculated as $R^2 = 0.88$ for grafted melon. At the same time, the relationship between ET and yield for grafted and ungrafted melons was determined to be $R^2 = 0.81$ and $R^2 = 0.88$, respectively. In general, in parallel with the increase in irrigation water and

ET, the yield values increased (Fig. 1). Grafting had a significant impact on the change in the number of fruits. In the ungrafted treatment, the number of fruits was higher than that in the ungrafted treatment (Fig. 2). A significant relationship between irrigation water and the number of fruits was found with a first-order equation in the form of 78% (R^2 = 0.78) in the ungrafted treatment and 80% (R^2 = 0.80) in the grafted treatment (Fig. 2). A relationship was found between the number of fruits and ET with a first-order equation in the form of 81% (R^2 = 0.81) in the ungrafted treatment and 88% (R^2 = 0.88) in the grafted treatment (Fig. 2). According to these findings, it might be suggested that the relationship between the number of fruits and ET might be estimated to be higher than the relationship between the number of fruits and irrigation. In other words, according to the results of the present study, there was a stronger effect of ET on the change in the number of fruits than irrigation water. Fruit weight was higher in the ungrafted treatments than in the grafted treatments (Fig. 3). There was a dramatic decrease in fruit weight in the grafted treatments, especially at the 40 and 60% irrigation levels, as the ET decreased (Fig. 3). The fact that the ky value is greater than 1 indicates that the examined plant is sensitive to water deficit, while the decrease in the ky value from 1 to 0 indicates that its sensitivity to water deficit is reduced (Doorenbos and Kassam 1979). In the grafted treatments, ky values were determined to be 0.21, 1.42 and 2.74 in the I_{80}, I_{60} and I_{40} treatments, respectively, for the entire growing season (Fig. 4). This showed that the grafted plant is more sensitive to water deficit than the ungrafted plant.

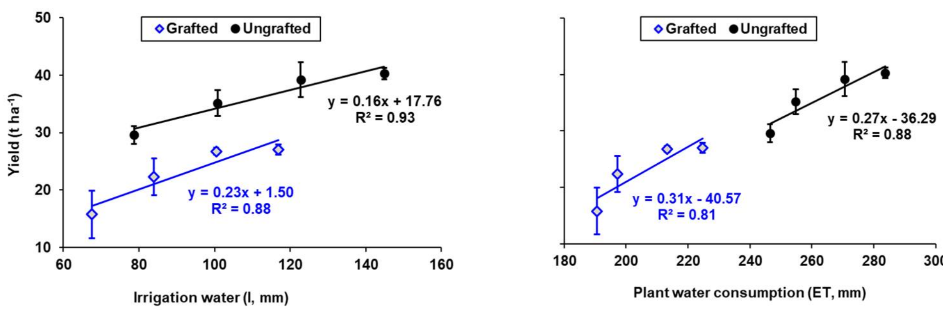

Fig. 1. Relationships between irrigation water-yield and ET-yield in grafted and ungrafted melons (R^2, the coefficient of determination).

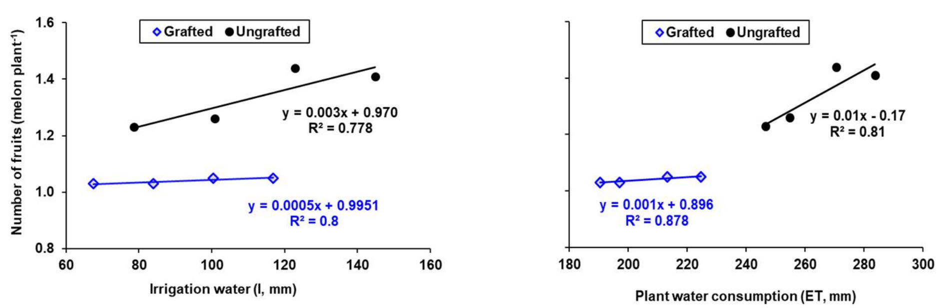

Fig. 2. Relationships between irrigation water-number of fruits and ET-number of fruits in grafted and ungrafted melons (R^2, the coefficient of determination).

Results reported by Yavuz *et al.* (2021) are similar to the ky values calculated of the present study. Such metabolites, which are activated by plants under water stress, have the ability to avoid a significant loss of yield and quality. In the present study, there was no significant loss in the yield, fruit number or fruit weight in the melon plants under low water stress conditions with a 20% water deficit, which supports this view.

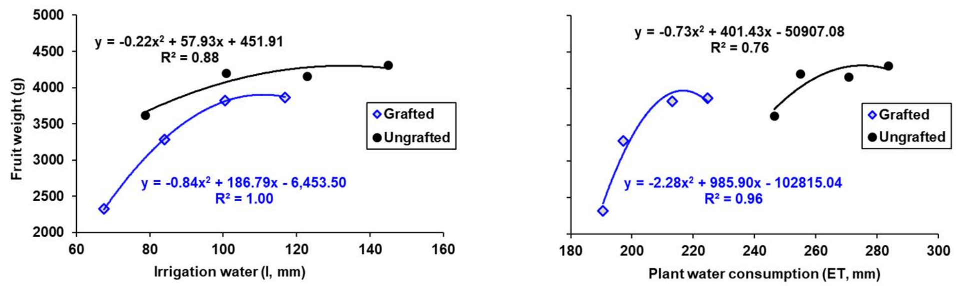

Fig. 3. Relationships between irrigation water-fruit weight and ET-fruit weight in grafted and ungrafted melons (R^2, the coefficient of determination).

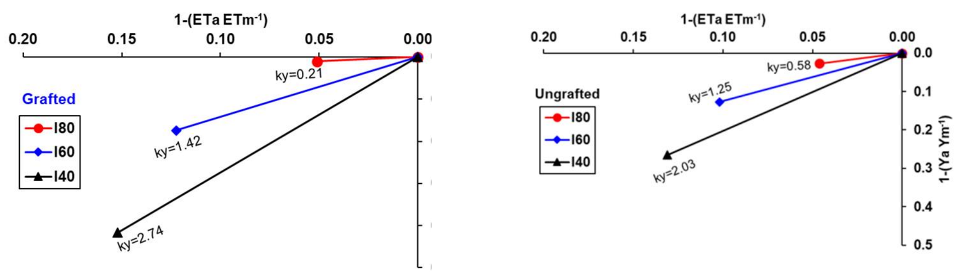

Fig. 4. Yield response factor (ky) in grafted and ungrafted melons.

The amount of irrigation water for melon cultivation in Mediterranean conditions can be safely reduced by 20%. However, the highest irrigation water use efficiency in the study was found in the 40% and 60% water deficit (I_{60} and I_{40}) treatments. However, there may be a significant loss in yield due to excessive water deficit on I_{40}. Therefore, in conditions where water is scarce or expensive, it is recommended that the water deficit rate applied during the melon growing period should not ideally exceed 40% of the amount of irrigation water.

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