

# Grafting effects on morphological development, yield performance, and fruit quality of melon (*Cucumis melo* L.)

Original Article

## Abstract:

This study aimed to evaluate the impact of grafting on yield and fruit quality parameters of melon (*Cucumis melo* L.) cultivated under arid environmental conditions. The need to enhance productivity while maintaining fruit quality is particularly relevant in water-limited regions, where melon production faces considerable challenges. The experiment was carried out in a greenhouse using a randomized block design. Melon scions (cv. MERBOUH) were grafted onto the interspecific rootstock *Cucurbita maxima* × *Cucurbita moschata* ('FERRO RZ') and compared with ungrafted controls. Agronomic traits, yield components, and fruit quality attributes were measured to assess the influence of grafting under controlled arid conditions. Grafting significantly affected most measured parameters. Grafted plants showed enhanced vegetative growth, with plant height being 53.85%, 38.10%, and 29.93% greater at 40, 60, and 90 days after planting, respectively. Yield components also improved, as average fruit weight increased by 55.38%, yield per plant by 61.54%, and total yield per hectare by 57.54%. Fruit size improved, with diameter and length increasing by 13.2% and 19.9%, respectively. In contrast, no significant differences were detected for pH, water content, or ash content. However, grafting reduced sweetness-related traits, with decreases of 11.2% in total sugars, 22.9% in reducing sugars, and 5.3% in sucrose content, highlighting a yield-quality trade-off. The study was successfully conducted under controlled greenhouse conditions in an arid environment, with no major constraints or unforeseen issues encountered throughout the growing season. The experimental setup allowed for consistent monitoring and reliable assessment of grafting effects on melon growth, yield, and fruit quality. This research provides new evidence that grafting melon onto the vigorous 'FERRO RZ' rootstock enhances productivity and fruit size in arid zones, although at the expense of sugar content. It offers practical insights into sustainable melon production strategies under water scarcity.

## Key words:

Melon (*Cucumis melo* L.), rootstock (FERRO RZ), fruit quality, yield performance, arid conditions

## Apstrakt:

Uticaj kalemljenja na morfološki razvoj, prinos i kvalitet plodova dinje (*Cucumis melo* L.)

Ova studija imala je za cilj da proceni uticaj kalemljenja na prinos i parametre kvaliteta ploda dinje (*Cucumis melo* L.) gajene u aridnim uslovima sredine. Potreba za unapređenjem produktivnosti uz očuvanje kvaliteta ploda naročito je izražena u područjima sa ograničenim vodnim resursima, gde se proizvodnja dinje suočava sa značajnim izazovima. Eksperiment je sproveden u plasteniku primenom randomizovanog blok dizajna. Plemke dinje (kultivar MERBOUH) kalemljene su na interspecijjski podlogu *Cucurbita maxima* × *Cucurbita moschata* ('FERRO RZ') i upoređene sa nekalemljenim kontrolama. Agronomске osobine, komponente prinosa i atributi kvaliteta ploda mereni su kako bi se procenio uticaj kalemljenja u kontrolisanim aridnim uslovima. Kalemljenje je značajno uticalo na većinu merenih parametara. Kalemljene biljke pokazale su pojačan vegetativni rast, pri čemu je visina biljke bila veća za 53,85%, 38,10% i 29,93% nakon 40, 60 i 90 dana od sadnje, redom. Komponente prinosa su takođe poboljšane: prosečna masa ploda povećana je za 55,38%, prinos po biljci za 61,54%, a ukupan prinos po hektaru za 57,54%. Veličina ploda je unapređena, sa povećanjem prečnika i dužine za 13,2% odnosno 19,9%. Nasuprot tome, nisu utvrđene značajne razlike u pH vrednosti, sadržaju vode ili pepela. Međutim, kalemljenje je smanjilo osobine povezane sa slatkoćom, sa smanjenjem ukupnih šećera za 11,2%, redukujućih šećera za 22,9% i sadržaja sahara za 5,3%, što ukazuje na kompromis između prinosa i kvaliteta. Studija je uspešno sprovedena u kontrolisanim plasteničkim uslovima u aridnoj sredini, bez većih ograničenja ili nepredviđenih problema tokom vegetacionog perioda. Eksperimentalna postavka omogućila je dosledno praćenje i pouzdanu procenu efekata kalemljenja na rast, prinos i kvalitet plodova dinje. Ovo istraživanje pruža nove dokaze da kalemljenje dinje na vigoroznu podlogu 'FERRO RZ' povećava produktivnost i veličinu ploda u aridnim zonama, ali na račun sadržaja šećera. Takođe nudi praktične smernice za održive strategije proizvodnje dinje u uslovima nedostatka vode.

## Ključne reči:

dinja (*Cucumis melo* L.), podloga ('FERRO RZ'), kvalitet ploda, prinos, aridni uslovi

Ameur Zaghouni

Department of Agricultural Sciences, University of Biskra, Algeria  
Research Laboratory of Ecosystem Diversity and Dynamics of Agricultural Production Systems in Drylands – DEDSPAZA, University of Biskra, Algeria  
ameur.zaghouni@univ-biskra.dz (Corresponding author)

Mohamed Rami Berbache

Higher School of Saharan Agriculture, Adrar, Algeria

Sarra Benaissa

Department of Agricultural Sciences, University of Biskra, Algeria  
Research Laboratory of Ecosystem Diversity and Dynamics of Agricultural Production Systems in Drylands – DEDSPAZA, University of Biskra, Algeria

Ayoub Hadjeb

Department of Agricultural Sciences, University of Biskra, Algeria  
Research Laboratory of Ecosystem Diversity and Dynamics of Agricultural Production Systems in Drylands – DEDSPAZA, University of Biskra, Algeria

Chaima Chetoui

Department of Agronomic Sciences, Laboratory of Improvement and Development of Plant and Animal Production, University of Sétif 1, Algeria

Received: November 20, 2025

Revised: April 13, 2026

Accepted: April 23, 2026



## Introduction

Grafting is an ancient agronomic technique and a form of vegetative or asexual plant propagation (Frey et al., 2023; Li et al., 2019). More specifically, grafting unites two or more pieces of living plant tissue, which then grow as a single plant (Mokhles et al., 2019).

The fundamental principle of grafting relies on using a vigorous root system from a commercial rootstock, which allows for increased absorption of water and minerals compared to self-rooted plants (Sallaku et al., 2022; Bhandari, 2021; Frey et al., 2023).

For a graft to be successful, it is essential that the vascular cambia of the scion and rootstock are in close contact and under appropriate pressure (Safari & Rezaei, 2021). This technique manipulates natural plant wound-healing mechanisms and requires a complex set of morphogenetic and developmental processes that first lead to tissue adhesion, followed by vascular reconnection between the two partners (Frey et al., 2023; Loupit & Cookson, 2020).

Grafting is widely used today in the production of woody fruit crops such as citrus, figs, apples, pears, and vines, as well as in various vegetable crops like tomatoes, watermelons, and cucumbers (Frey et al., 2023; Loupit & Cookson, 2020). This technique allows combining desirable traits, such as disease resistance from the rootstock and superior fruit quality from the scion (Frey et al., 2023).

Grafting represents a modern and increasingly recognized technique for improving crop productivity, particularly under challenging environmental conditions (Saleh, 2018). This method involves combining a scion (the desired variety) with a resistant rootstock, offering numerous advantages in terms of growth and yield, including tolerance to salt stress and improved yield and fruit quality in melon (Saleh, 2018). The use of grafted plants has increased significantly in horticulture due to the growing demand for higher yields and increased tolerance to biotic and abiotic stresses (Camalle et al., 2023).

This study aims to analyze the performance differences between melon scions (cv. MERBOUH) grafted onto 'FERRO RZ' rootstock and non-grafted plants, based on key agronomic parameters of yield and fruit quality under arid greenhouse conditions.

## Materials and Methods

### Study site

Sidi Okba is situated in the southeastern region of Algeria, specifically 10 km southeast of Biskra. The precise geographical coordinates are 34°44'54.44"N and 5°53'59.98"E (Fig. 1) (Merabti et al., 2019).

The Sidi Okba region has an arid-to-semiarid Mediterranean climate, marked by an extended summer drought (Bengouga et al., 2019). Winter conditions are defined by a frigid and arid climate, including infrequent morning frosts, with low temperatures in December and January ranging from -2 to +4 °C (Bengouga et al., 2019). Conversely, summer is marked by elevated temperatures and arid conditions, with maximum temperatures above 40 °C in July and August (Bengouga et al., 2019).

### Experimental Setup

#### Plant material used

The variety of melon used for this crop comes from F1 hybrid seeds, MERBOUH, grafted onto an F1 FERRO RZ rootstock intended to be grown under greenhouse shelters. It is known to be an early variety with indeterminate growth, exhibiting good vigor and disease resistance.

#### Grafting technique (using the Japanese method)

Tube grafting/Splice grafting: also called "Japanese top grafting" or "slant-cut grafting," this method involves cutting the rootstock below the cotyledons at an angle of 45-60°, then attaching the cut scion at the same angle above the cotyledons (Caradonia et al., 2020; Pardo-Alonso et al., 2020; Penella & Calatayud, 2018). This technique has a high success rate and is relatively simple to execute, making it suitable for automation (Pardo-Alonso et al., 2020).

Tube grafting requires meticulous preparation of the seedlings. Seedlings are grafted when they have 4 fully developed true leaves (Caradonia et al., 2020). The rootstock is cut below the cotyledons to prevent regrowth, with a pronounced angle that creates a larger contact surface than a flat cut, allowing more cells from the cut surfaces of both the rootstock and the scion to come into contact and fuse better (Pardo-Alonso et al., 2020). Cuts at approximately 45° are made on the rootstock and the scion using a well-sharpened razor blade (Vu et al., 2021). Elastic grafting clips in the form of a tube with a stick are used to maintain cohesion between the scion and the rootstock (Caradonia et al., 2020).

### Morphological Parameters

#### Average height of the plants

The average plant height was measured from the soil level to the apical tip of the stem. Three measurements were taken during the growing cycle: 30, 60, and 90 days after planting. These measurements allow tracking the height-growth dynamics of the plants.

### Production parameters

#### Average number of fruits per plant

The counting of harvested fruits was carried out for each plant at each harvest. The average obtained reflects the individual fruit productivity.

#### Average production per plant

The average production per plant corresponds to the sum of the weights of the harvested fruits, expressed in kilograms (kg). It reflects the overall performance of each plant in terms of yield.

#### Average fruit weight

The average weight of a fruit was obtained by dividing the total production of a plant by the total number of fruits it produced. This data, expressed in kilograms, serves as an indicator of fruit size and individual quality.

#### Total yield

The total yield of the crop was estimated in quintals per hectare (qx/ha), based on average productions and planting density.

### The assessment of fruit dimensions

The primary characteristics consist of the polar diameter (longitudinal) and the equatorial diameter (transverse), measured with digital calipers (Lian et al., 2021). The approach entails a longitudinal incision at the midpoint to facilitate accurate measurement of both diameter and length (Oliveira et al., 2023).

### Determination of the pH of melon fruit

Weigh 10 g of melon cut into small pieces, blend them thoroughly with 100ml of distilled water in a blender, filter the melon juice with a centrifuge, and determine the pH with a pH meter (Paulauskienė et al., 2020).

### Determining the water content and ash content of the melon fruit

The determination of water content in melon can be performed using several analytical methods. The reference method consists of oven drying according to the recommendations of the Association of Official Analytical Chemists (AOAC), in which approximately 10 g of sample is dehydrated in an air

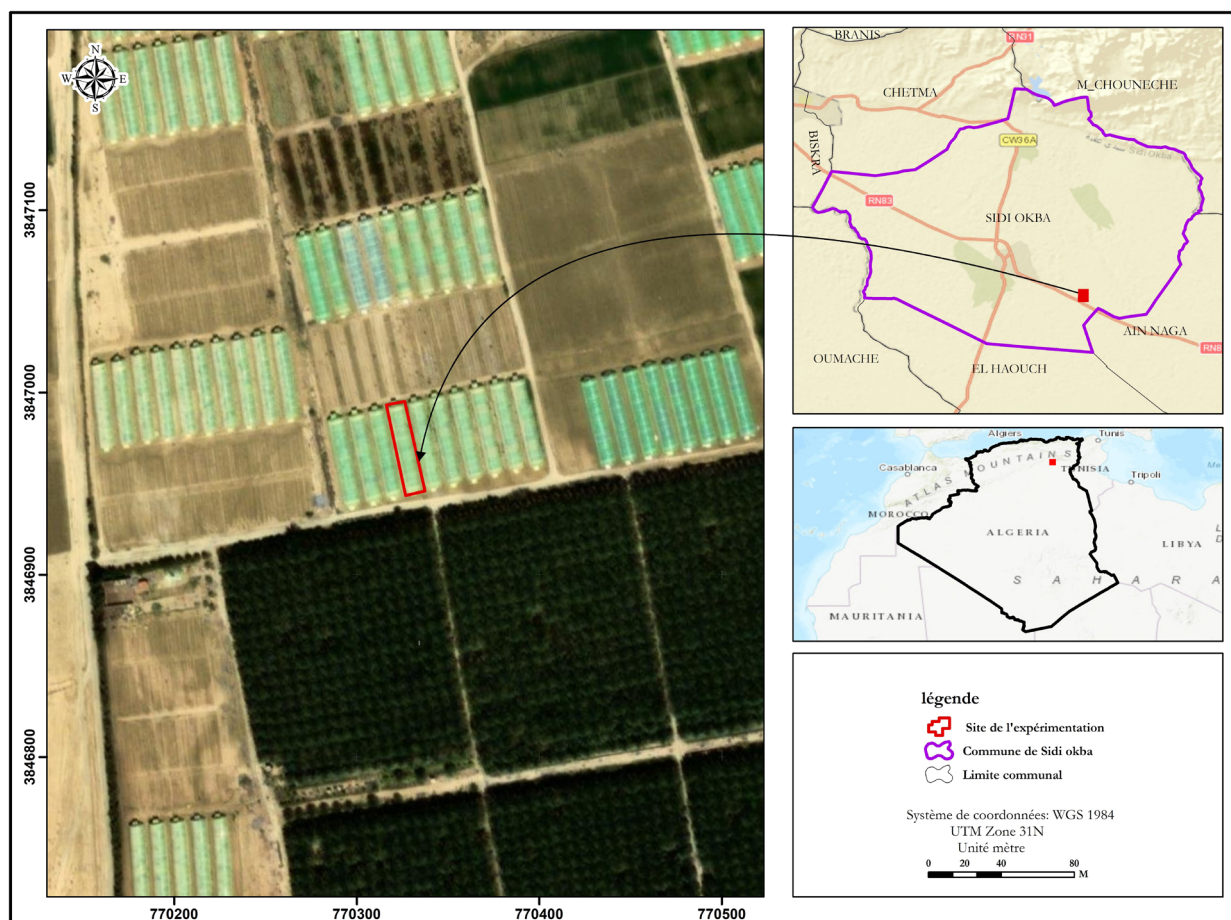


Fig. 1. Localisation of the experimentation station in the study area

oven at 105 °C until a constant weight is obtained (Sroy et al., 2022). This approach allows for the calculation of moisture content as the difference between the fresh weight and the dry weight, divided by the fresh weight and expressed as a percentage.

For the determination of ash content, the official AOAC methods are employed (Devi et al., 2019). This technique involves the complete incineration of the dried sample to eliminate all organic matter, leaving only the mineral residues. The measurements are carried out using high-precision analytical balances ( $\pm 0.0001$  g) to ensure the reproducibility of the results (Sroy et al., 2022).

**Determination of the content of reducing sugars, total sugars, and sucrose**

Titration methods offer classic volumetric approaches for determining the sugar content of melon via redox reactions with copper-based reagents. The Lane-Eynon method represents a standardized approach that follows established protocols to measure reducing and total sugars (Szydłowska et al., 2022). For the determination of reducing sugar, the clarified fruit solution is titrated against a mixed Fehling’s solution using methylene blue as an indicator, in accordance with the AOAC 932.12 method. The analysis of total sugar requires acid hydrolysis before titration, in which citric acid is added to the sample, and the mixture is boiled to complete the inversion of sucrose into reducing sugars (Hellen Lugwisha, 2016).

Sucrose content = Total sugars – Reducing sugars (Ferreira et al., 2021).

**Statistical analyses**

The statistical analysis of the data is carried out using OriginPro 2025, version 10.2.0.196. The

chosen statistical test is Student’s, used to compare the independent variables of melon cultivation between grafted and non-grafted plants, at a significance level of  $\alpha=5\%$ .

**Results**

The soil analysis (**Tab. 1**) indicates a moderately alkaline, saline growing medium (pH 7.20; CE = 6.74 dS/m), with low organic matter (2.66%) and nitrogen (0.070%), conditions typical of arid environments. The exceptionally high available phosphorus ( $P_2O_5 = 749.23$  ppm) and elevated  $Na^+$  and  $Cl^-$  concentrations highlight the challenging edaphic context, further justifying the use of the stress-tolerant ‘FERRO RZ’ rootstock in this experiment.

A comparison of the growth and yield characteristics of melon plants using the method of grafting technique compared to ungrafted plants is presented in **Tab. 2**.

The growth of the plants was measured three times throughout their growth cycle. The growth rates observed were as follows:

For the ungrafted plants group, the growth rate was 0.52 cm after 30 days and 1.05 cm after 60 days. For the group of grafted plants, the growth rate was 0.80 cm after 30 days and 1.45 cm after 60 days. After 90 days of transplantation, the growth rates displayed higher values as follows: 1.47 cm for the ungrafted plants group, 1.91 cm for the grafted plants group. Based on statistical analysis, the grafted plants exhibited significant differences in growth compared to the ungrafted plants group throughout the three measurements ( $p<0.0001$ ).

Based on **Tab. 2**, the results show that grafted plants had higher yields (4.20 kg) than the ungrafted plants group (2.60 kg per plant). The grafted plants

**Table 1.** The chemical analysis of the experimental soil

|      | CE 1/5 | pH    | MO   | N    | P <sub>2</sub> O <sub>5</sub> | K <sub>2</sub> O | Na <sup>+</sup> | Ca <sup>2+</sup> | Mg <sup>2+</sup> | K <sup>+</sup> | HCO <sub>3</sub> <sup>-</sup> | Cl <sup>-</sup> |
|------|--------|-------|------|------|-------------------------------|------------------|-----------------|------------------|------------------|----------------|-------------------------------|-----------------|
|      | (dS/m) | 1-May | (%)  | (%)  | (ppm)                         |                  |                 |                  | (méq/L)          |                |                               |                 |
| Soil | 6.74   | 7.2   | 2.66 | 0.07 | 749.23                        | 52.32            | 18.55           | 17.8             | 10.4             | 4.44           | 2                             | 23.58           |

**Table 2.** Impact of grafting on yield and morphological aspects of melon

| Treatment        | Plant Height 30 Days (cm) | Plant Height 60 Days (cm) | Plant Height 90 Days (cm) | N° of Fruit/ Plant | Fruit weight (kg) | Yield/ Plant (kg) | Yield/ha (qx) |
|------------------|---------------------------|---------------------------|---------------------------|--------------------|-------------------|-------------------|---------------|
| Grafted plants   | 0.80 b                    | 1.45 b                    | 1.91 b                    | 3.00 b             | 2.02 b            | 4.20 b            | 512.00 b      |
| Ungrafted plants | 0.52 a                    | 1.05 a                    | 1.47 a                    | 2.00 a             | 1.30 a            | 2.60 a            | 325.00 a      |
| p values         | <0.0001                   | <0.0001                   | <0.0001                   | 0.008              | <0.0001           | <0.0001           | <0.0001       |

achieved the highest average fruit weight (2.02 kg), followed by the ungrafted plants group (1.30 kg) ( $p < 0.0001$ ). Regarding the number of fruits per plant, the grafted plants group yielded the highest number, with 3 fruits per plant ( $p < 0.0001$ ). The most significant impact of grafting was observed on yield per hectare. The grafted plants gave a yield of (512.00 qx/ha), while the non-grafted plants only gave (325.00 qx/ha) ( $p < 0.0001$ ).

Furthermore, the results shown in **Tab. 3** show that the grafted plants group had an average caliber of 47.60 cm and a length of 26.15 cm. By contrast, the ungrafted plants group exhibited the smallest dimensions, with an average caliber of 42.05 cm and a length of 21.82 cm. Regarding pH, water content, and ash content, no significant differences were detected for pH ( $p > 0.393$ ), water content ( $p > 0.402$ ), and ash content ( $p > 0.211$ ) between the two groups of plants.

As for sugars, sugar content showed an inverse trend. The ungrafted plants showed higher levels of total sugars (7.77 g/100 g) compared to 6.90 g/100 g for the grafted plants ( $p < 0.0001$ ), the reducing sugars (3.05 g/100 g) for the ungrafted plants group, and (2.35 g/100 g) for the grafted plants group ( $p < 0.0001$ ). The sucrose concentration showed a notable disparity, with elevated levels observed in the ungrafted plants group (4.72 g/100 g) compared to the grafted plants group (4.47 g/100 g;  $p = 0.040$ ).

The correlation matrix (**Fig. 2**) revealed strong positive relationships among most morphological and yield-related traits, whereas sucrose content was negatively correlated with these parameters. The length and caliber of fruit demonstrated significant correlations with both fruit weight (0.95, 0.89) and overall yield (0.93, 0.91). At 90 days, plant height showed strong correlations with fruit weight (0.96), production per plant (0.97), and yield per hectare (0.98), underscoring the importance of vegetative growth in yield formation. The number of fruits per plant was moderately correlated with yield (0.56), indicating that yield gains are more closely associated with fruit size and weight than with fruit quantity. Similarly, sucrose concentration was negatively correlated with fruit weight (-0.41), number of fruits per plant (-0.30), and yield (-0.43),

indicating an inverse relationship between sugar accumulation and yield performance. The yield was predominantly influenced by fruit weight (0.97) and production per plant (0.99), both of which are intricately linked to vegetative development and fruit morphological characteristics.

## Discussion

This study demonstrated that grafting the melon scion 'MERBOUH' onto the 'FERRO RZ' rootstock in arid greenhouse conditions significantly enhanced vegetative growth and yield attributes, but it reduced fruit sugar content. These findings contribute to the expanding knowledge of grafting in cucurbits and enhance our comprehension of plant physiological and agronomic responses in arid conditions. Examining the mechanisms and comparative literature provides insights into how the interactions between rootstock and scion influence plant performance across various dimensions, including morphological and biochemical alterations. Our data confirm that grafting significantly increased plant height throughout the growth cycle, aided by the vigorous root system of 'FERRO RZ', which enhances nutrition and water uptake and tolerance to abiotic stresses prevalent in arid environments (Ohletz & Loy, 2021). The elevation in plant height signifies not merely quantitative alteration; it also reflects a modification in resource utilization. The robust architecture of the rootstock enhances hydraulic conductivity and mineral uptake, hence accelerating cell elongation and division in the scion. Grafted plants exhibited robust vegetative development 4 to 5 weeks post-transplantation, consistent with studies indicating heights above 203 to 205 cm in certain rootstock-scion combinations (Mavlyanova & Lyan, 2022). This rapid growth indicates that the rootstock and scion began to collaborate promptly. This may have resulted from hormonal signals such as auxins and cytokinins that promote shoot growth.

The advantage of growth was particularly evident when the plants experienced stress. This aligns with the findings of Ulas et al. (2019), which demonstrated that grafted melons exhibited increased height, thicker stems, and greater leaf area under saline conditions,

**Table 3.** Impact of grafting on the qualitative aspects of melon

| Treatment        | Caliber (cm) | Length (cm) | pH     | Water content (%) | Ash content g/100g | Total sugar g/100 g MF | Reducing sugar g/100 g MF | Sucrose g/100 g MF |
|------------------|--------------|-------------|--------|-------------------|--------------------|------------------------|---------------------------|--------------------|
| Grafted plants   | 47.60 b      | 26.15 b     | 8.02 a | 90.81 a           | 9.36 a             | 6.90 a                 | 2.35 a                    | 4.47 a             |
| Ungrafted plants | 42.05 a      | 21.82 a     | 8.00 a | 90.40 a           | 9.77 a             | 7.77 b                 | 3.05 b                    | 4.72 b             |
| <i>p</i> values  | <0.0001      | <0.0001     | 0.393  | 0.402             | 0.211              | <0.0001                | <0.0001                   | 0.04               |



**Fig. 2.** Correlation matrix between the studied parameters

as well as with the results of Luxi et al. (2019), which indicated analogous advantages in the absence of stress. In our arid greenhouse, characterized by low soil moisture and elevated evapotranspiration rates, the grafted plants likely thrived due to the rootstock's ability to maintain turgor pressure and osmotic regulation, thereby preventing wilting and sustaining photosynthesis. The enhanced nutrient absorption capacity of the rootstock (Ohletz & Loy, 2021) likely contributed to the observed increase in biomass and plant height in our trial, demonstrating the efficacy of grafting under challenging conditions. Furthermore, these morphological improvements may correlate with increased photosynthetic efficiency, as larger leaf areas facilitate greater carbon fixation, hence enhancing overall plant vitality in resource-limited environments.

Grafting enhanced all yield components, including fruit quantity, weight, and overall yield, consistent with previous research on robust rootstocks such as *Cucurbita* hybrids (Kyriacou et al., 2017; Nie & Wen, 2023). In our trial, the 'FERRO RZ' rootstock enhanced floral induction and fruit set, resulting in increased fruit yield per plant, potentially attributable to superior assimilate partitioning from the augmented root system. Our findings indicated that grafted 'MERBOUH' plants yielded a higher fruit count per plant, with appropriate rootstock-scion combinations enhancing average fruit weight by as much as 55%, an effect further intensified by pruning, particularly in large-fruited cultivars (Kyriacou et al., 2017; Zaaroor-Presman et al., 2020). The increase in weight may result from enhanced sink strength in the fruits, which attracts more photoassimilates from the scion, aided by the rootstock's effective vascular connections.

Total yield improvements ranged from 16.3% to 89.2%, similar to rootstocks such as Code 45, which produced 4.5 kg/m<sup>2</sup> compared with 3 kg/m<sup>2</sup> for non-grafted controls (Nazarpour et al., 2025; Zhang et al., 2019). The advancements in our study highlight the combinatorial consequences of augmented fruit quantity and weight, possibly influenced by rootstock-derived signals that postpone senescence and prolong the fruiting duration. Incompatible pairings, however, can lead to yield declines (Camalle et al., 2023), underscoring the necessity of meticulous rootstock selection to prevent phloem obstruction or hormonal imbalances that could hinder nutrient transfer.

The fruit dimensions were enhanced, with grafted specimens showing increased length and diameter; specifically, the TZ 148/H27 rootstock yielded fruits measuring 12.88 cm in length and 14.16 cm in diameter (Adigüzel et al., 2023). Sanmiguel et al. (2025) observed comparable improvements in fruit size, highlighting the significance of rootstock compatibility in facilitating cell proliferation via enhanced water and nutrient availability. Management practices such as pruning have increased yield and fruit size (Zaaroor-Presman et al., 2020), indicating that combining grafting with cultural techniques could optimize productivity in arid systems by reducing competition among sinks and enhancing light penetration into lower canopy layers.

Grafting had no effect on pH, moisture content, or ash content, indicating that the water balance and mineral composition remained largely unchanged (Al-Mawaali et al., 2019; Cáceres et al., 2017). This stability suggests that the rootstock-scion interface does not disrupt the scion's inherent osmotic regulation or ionic equilibrium, hence maintaining the essential physicochemical integrity of the fruit in the face of external stressors. Our findings, however, indicated a reduction in total sugars, reducing sugars, and sucrose. This aligns with observations of *Cucurbita*-type rootstocks, such as Shintoza, which significantly reduce glucose and fructose levels (Flores-León et al., 2021). This reduction may result from dilution effects caused by heightened fruit volumes or alterations in carbohydrate metabolism, wherein the robust rootstock prioritises biomass accumulation over sugar storage in the fruit pulp. *Cucumis*-type rootstocks (e.g., F1 Pat81 and Fian) demonstrated a diminished impact, primarily

reducing glucose concentrations (Flores-León et al., 2021). Conversely, some studies indicated that grafted melons and watermelons did not alter total soluble sugar content (Kyriacou et al., 2017; Trandel et al., 2021). This indicates that the variations were attributable to rootstock type, scion genetics, and environmental conditions, such as elevated temperatures and low humidity in our arid greenhouse. In these situations, elevated respiration rates may accelerate carbohydrate breakdown, exacerbating the observed declines. The disparities may result from differences in the quantity of sugar transporters or enzymes, such as invertase and sucrose synthase, at the graft union, influenced by signals from the rootstock. The reductions in sugar content, while statistically significant, may not substantially impact fruit marketability in yield-oriented markets (Kyriacou et al., 2017), as sensory thresholds for sweetness perception may still be attained based on the cultivar's baseline values.

## Conclusion

Grafting the 'MERBOUH' melon onto the 'FERRO RZ' rootstock consistently enhanced vegetative vigor, yield components, and fruit dimensions under arid greenhouse conditions, thereby affirming the rootstock's efficacy as a productivity-enhancing tool in water-limited environments. The primary trade-off, an increased yield at the expense of sugar accumulation, likely indicates a rootstock-induced shift in carbon partitioning towards biomass rather than soluble solids, a pattern observed in cucurbit-type rootstocks within other cucurbit systems. Importantly, pH, water content, and ash content remained stable, suggesting that the rootstock-scion interface maintains the fruit's fundamental physicochemical integrity. Collectively, these findings position 'FERRO RZ' as well-suited for yield-focused markets, while highlighting that markets sensitive to sweetness may necessitate alternative rootstock selections or complementary agronomic modifications. Future research should elucidate the molecular and enzymatic mechanisms regulating sugar transport at the graft union, particularly invertase and sucrose synthase activity, explore a broader range of rootstock-scion combinations capable of decoupling the yield-sweetness trade-off, and investigate whether targeted cultural interventions such as adjusted irrigation deficit, canopy management, or harvest timing can restore fruit quality without compromising the yield benefits conferred by grafting.

## References

- Adigüzel, P., Namlı, M., Nyirahabimana, F., Solmaz, İ., & Sari, N. (2023). The effects of grafting on plant, fruit and seed quality in cantaloupe (*Cucumis melo* L. var. *cantalupensis*) melons. *Seeds*, 2(1), 1–14. <https://doi.org/10.3390/seeds2010001>
- Al-Mawaali, Q., Al-Sadi, A. M., Al-Said, F. A., Rahman, M. S., Al-Zakwani, I., Ali, A., Al-Yahyai, M., & Deadman, M. L. (2019). Effect of grafting on resistance to vine decline disease, yield and fruit quality in muskmelon cv. Sawadi. *Journal of Agricultural and Marine Sciences*, 23(1), 2–10. <https://doi.org/10.24200/jams.vol23iss1pp2-10>
- Bengouga, K., Lahmadi-Salwa, L., Zeguerou, R., Maaoui, M., & Halis, Y. (2019). Livestock in rural piedmont regions of Algeria. *Biotechnology in Animal Husbandry*, 35(2), 199–208. <https://doi.org/10.2298/BAH1902199B>
- Bhandari, N. (2021). Seasonal variability and propagation environment to graft success and growth of sapling in tropical and subtropical fruit crops: A review. *Agricultural Reviews*. <https://doi.org/10.18805/ag.R-161>
- Cáceres, A., Perpiñá, G., Ferriol, M., Picó, B., & Gisbert, C. (2017). New *Cucumis* rootstocks for melon: 'UPV-FA' and 'UPV-FMy'. *HortScience*, 52(5), 792–797. <https://doi.org/10.21273/HORTSCI11791-17>
- Camalle, M. D., Pivonia, S., Zurgil, U., Fait, A., & Tel-Zur, N. (2023). Rootstock identity in melon–pumpkin graft combinations determines fruit metabolite profile. *Frontiers in Plant Science*, 13, 1024588. <https://doi.org/10.3389/fpls.2022.1024588>
- Caradonia, F., Ronga, D., Flore, A., Barbieri, R., Moulin, L., Terzi, V., & Francia, E. (2020). Biostimulants and cherry rootstock increased tomato fruit yield and quality in sustainable farming systems. *Italian Journal of Agronomy*, 15(2), 1553. <https://doi.org/10.4081/ija.2020.1553>
- Devi, S., Kumar Mahato, D., Singh, S., & Prasad Singh, S. (2019). Optimization of process variables for retention of functional properties of bitter melon (*Momordica charantia* L.) and its shelf-life extension. *Current Agriculture Research Journal*, 7(1), 74–89. <https://doi.org/10.12944/CARJ.7.1.10>
- Ferreira, L. F. P., Bogéa, A. L. G., Rosário, M. S. D., Silva, A. C. L. N., & Costa, M. C. P. (2021). Sensorial, physicochemical and microbiological analyses of honey samples produced by *Apis mellifera* in the region of Cocais Maranhenses, Maranhão State, Brazil. *Research, Society and Development*, 10(7), e21510716495. <https://doi.org/10.33448/rsd-v10i7.16495>
- Flores-León, A., García-Martínez, S., González,

- V., Garcés-Claver, A., Martí, R., Julián, C., Sifres, A., Pérez-de-Castro, A., Díez, M. J., López, C., Ferriol, M., Gisbert, C., Ruiz, J. J., Cebolla-Cornejo, J., & Picó, B. (2021). Grafting snake melon (*Cucumis melo* L. subsp. *melo* var. *flexuosus* [L.] Naudin) in organic farming: Effects on agronomic performance, resistance to pathogens, sugar, acid and VOC profiles, and consumer acceptance. *Frontiers in Plant Science*, 12, 613845. <https://doi.org/10.3389/fpls.2021.613845>
- Frey, C., Martínez-Romera, N., Encina, A., & Acebes, J. L. (2023). Immunohistochemical dynamics of cell wall matrix polymers during tomato autograft healing. *Plant Molecular Biology*, 113(6), 353–365. <https://doi.org/10.1007/s11103-023-01351-7>
- Guan, W., Zhao, X., & Huber, D. J. (2015). Grafting with an interspecific hybrid squash rootstock accelerated fruit development and impaired fruit quality of Galia melon. *HortScience*, 50(12), 1833–1836. <https://doi.org/10.21273/HORTSCI.50.12.1833>
- Hellen Lugwisha, E. (2016). Postharvest changes in physicochemical properties and levels of some inorganic elements in sugar apple (*Annona squamosa* L.) fruits of Coast Region, Tanzania. *Journal of Food and Nutrition Sciences*, 4(3), 41. <https://doi.org/10.11648/j.jfns.20160403.11>
- Kyriacou, M. C., Rouphael, Y., Colla, G., Zrenner, R., & Schwarz, D. (2017). Vegetable grafting: The implications of a growing agronomic imperative for vegetable fruit quality and nutritive value. *Frontiers in Plant Science*, 8, 741. <https://doi.org/10.3389/fpls.2017.00741>
- Li, Y., Sun, W., Liu, F., Cheng, J., Zhang, X., Zhang, H., & Zhao, Y. (2019). Methods for grafting *Arabidopsis thaliana* and *Eutrema salsugineum*. *Plant Methods*, 15(1), 93. <https://doi.org/10.1186/s13007-019-0477-x>
- Lian, Q., Fu, Q., Xu, Y., Hu, Z., Zheng, J., Zhang, A., He, Y., Wang, C., Xu, C., Chen, B., Garcia-Mas, J., Zhao, G., & Wang, H. (2021). QTLs and candidate genes analyses for fruit size under domestication and differentiation in melon (*Cucumis melo* L.) based on high-resolution maps. *BMC Plant Biology*, 21(1), 126. <https://doi.org/10.1186/s12870-021-02904-y>
- Loupit, G., & Cookson, S. J. (2020). Identifying molecular markers of successful graft union formation and compatibility. *Frontiers in Plant Science*, 11, 610352. <https://doi.org/10.3389/fpls.2020.610352>
- Luxi, Y., Yongdong, X., Wenyi, Y., & Zhong-qun, H. (2019). Effects of grafting on sugar metabolism of melon (*Cucumis melo* L.) seedlings under copper stress. *IOP Conference Series: Earth and Environmental Science*, 295(3), 032092. <https://doi.org/10.1088/1755-1315/295/3/032092>
- Mavlyanova, R. F., & Lyan, E. E. (2022). Increasing the yield of melon in a greenhouse by vegetative grafting on vegetable marrow rootstocks. *Vegetable Crops of Russia*, 4, 55–59. <https://doi.org/10.18619/2072-9146-2022-4-55-59>
- Merabti, B., Lebbouz, I., Nouioui, I., Aissaoui, H., & Ouakid, M. L. (2018). Assessment of the insecticidal property of pepper (*Capsicum annuum*) extracts on the larval stages of the tomato leafminer *Tuta absoluta* (Lepidoptera: Gelechiidae). *Journal of Bio-Science*, 26, 25–30.
- Mokhles, A., Kumar, P., Sharma, P., & Thakur, V. (2019). Effect of rootstocks and grafting techniques on quality of tomato (*Solanum lycopersicum* L.) under polyhouse conditions. *International Journal of Current Microbiology and Applied Sciences*, 8(7), 80–85. <https://doi.org/10.20546/ijcmas.2019.807.011>
- Nazarpour, A., Azizi, M., Samadi, S., Aroiee, H., Farhadi, A., Muhammad, M., & Morshedloo, M. R. (2025). Rootstock and grafting type affect the growth and oil quality of medicinal pumpkin (*Cucurbita pepo* var. *styriaca*). *BMC Plant Biology*, 25(1), 528. <https://doi.org/10.1186/s12870-025-06571-1>
- Nie, W., & Wen, D. (2023). Study on the applications and regulatory mechanisms of grafting on vegetables. *Plants*, 12(15), 2822. <https://doi.org/10.3390/plants12152822>
- Ohletz, J. L., & Loy, J. B. (2021). Grafting melons increases yield, extends the harvest season, and prevents sudden wilt in New England. *HortTechnology*, 31(1), 101–114. <https://doi.org/10.21273/HORTTECH04669-20>
- Oliveira, R. R. T., Oliveira, F. D. A. D., Góis, H. M. D. M. N., Menezes, P. V. D., Santos, S. T. D., Aroucha, E. M. M., & Almeida, J. G. L. D. (2023). Salt stress and K/Ca ratios of the nutrient solution in the production and quality of melon. *Revista Ciência Agronômica*, 54. <https://doi.org/10.5935/1806-6690.20230052>
- Pardo-Alonso, J.-L., Carreño-Ortega, Á., Martínez-Gaitán, C.-C., & Fatnassi, H. (2020). Behavior of different grafting strategies using automated technology for splice grafting technique. *Applied Sciences*, 10(8), 2745. <https://doi.org/10.3390/app10082745>

org/10.3390/app10082745

**Paulauskienė, A., Tarasevičienė, Ž., & Šileikienė, D.** (2020). Quality evaluation of hardy kiwifruit (*Actinidia kolomikta*) using non-destructive and holistic research methods. *Rural Development*, 2019(1), 51–56. <https://doi.org/10.15544/RD.2019.039>

**Penella, C., & Calatayud, A.** (2018). Pepper crop under climate change: Grafting as an environmentally friendly strategy. In C. S. Rao, A. K. Shanker, & C. Shanker (Eds.), *Climate resilient agriculture—Strategies and perspectives*. InTech. <https://doi.org/10.5772/intechopen.72361>

**Safari, M., & Rezaei, M.** (2021). Grafting success of *Berberis integerrima* cv. Bidaneh on wild type barberries. *International Journal of Fruit Science*, 21(1), 1030–1039. <https://doi.org/10.1080/15538362.2021.1975012>

**Saleh, S.** (2018). Effect of grafting technique on productivity and quality of cantaloupe under saline irrigation water. *Current Investigations in Agriculture and Current Research*, 2(1). <https://doi.org/10.32474/CIACR.2018.02.000128>

**Sallaku, G., Rewald, B., Sandén, H., & Balliu, A.** (2022). Scions impact biomass allocation and root enzymatic activity of rootstocks in grafted melon and watermelon plants. *Frontiers in Plant Science*, 13, 949086. <https://doi.org/10.3389/fpls.2022.949086>

**Sanmiguel, J., Andrade, V., Vargas-Tierras, Y., Samaniego, I., Paredes-Arcos, F., Vásquez-Castillo, W., & Viera-Arroyo, W.** (2025). Physical-chemical characterization of fruit harvested at different maturity stages of grafted yellow pitahaya (*Selenicereus megalanthus* Haw.). *Plants*, 14(2), 178. <https://doi.org/10.3390/plants14020178>

**Sroy, S., Miller, F. A., Fundo, J. F., Silva, C. L. M., & Brandão, T. R. S.** (2022). Freeze-drying processes applied to melon peel: Assessment of physicochemical attributes and intrinsic microflora survival during storage. *Foods*, 11(10), 1499. <https://doi.org/10.3390/foods11101499>

**Szydłowska, A., Zielińska, D., & Kolożyn-Krajewska, D.** (2022). Effect of pumpkin cultivar on selected quality parameters of functional non-dairy frozen desserts. *Applied Sciences*, 12(16), 8063. <https://doi.org/10.3390/app12168063>

**Trandel, M. A., Johanningsmeier, S., Schultheis, J., Gunter, C., & Perkins-Veazie, P.** (2021). Cell wall polysaccharide composition of grafted ‘Liberty’ watermelon with reduced incidence of hollow heart defect. *Frontiers in Plant Science*, 12, 623723. <https://doi.org/10.3389/fpls.2021.623723>

**Ulas, F., Aydın, A., Ulas, A., & Yetisir, H.** (2019). Grafting for sustainable growth performance of melon (*Cucumis melo*) under salt-stressed hydroponic conditions. *European Journal of Sustainable Development*, 8(1). <https://doi.org/10.14207/ejsd.2019.v8n1p201>

**Uppar, J., & Shastri, Y.** (2025). A comprehensive review on cucurbit grafting: A sustainable approach to boost crop performance. *Advances in Research*, 26(1), 74–83. <https://doi.org/10.9734/air/2025/v26i11234>

**Vu, N.-T., Park, J.-M., Nguyen, N.-Q., Nguyen, T.-T.-S., Kim, I.-S., & Jang, D.-C.** (2021). Enhanced drought tolerance of Arabica coffee (*Coffea arabica* L.) by grafting method. *Sains Malaysiana*, 50(11), 3219–3229. <https://doi.org/10.17576/jsm-2021-5011-06>

**Zaaroor-Presman, M., Alkalai-Tuvia, S., Chalupowicz, D., Beniches, M., Gamliel, A., & Fallik, E.** (2020). Watermelon rootstock/scion relationships and the effects of fruit thinning and stem pruning on yield and postharvest fruit quality. *Agriculture*, 10(9), 366. <https://doi.org/10.3390/agriculture10090366>

**Zhang, J., Wang, P., Tian, H., Wang, Y., & Jiang, H.** (2019). Using a new hybrid rootstock significantly increases the grafted plant rate and watermelon yield. *International Agrophysics*, 33(1), 97–106. <https://doi.org/10.31545/intagr/104402>

