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Physiological and chemical performance of the Flame seedless grapevine cultivar in the presence of Paulsen 1103 as the interstock

Desempenho fisiológico e químico da cultivar de videira Flame sem sementes na presença de Paulsen 1103 como enxerto intermediário

Mohamed Ahmed Fayek[1], Amr Ebrahim Mohamed Ali[1*], Ahmed Abdelhady Rashedy[1]

[1]Cairo University, Faculty of Agriculture, Pomology Department, Giza, Egypt
[*]Corresponding author: amrebrahim1991@yahoo.com
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ABSTRACT

Interstock is commonly used in deciduous fruit trees as a sustainable strategy to reduce the vigor of the scion associated with the high quality of fruits. In this study, we tested the effect of Paulsen 1103 (*Vitis berlandieri* x *Vitis rupestris*) as interstock on the grafting success, growth, and the physiological and chemical parameters of Flame seedless (*Vitis vinifera*) grapevine grafted onto Freedom (*Vitis champinii* x 1613C) and Paulsen 1103 rootstocks. This study was conducted over two seasons (2019 and 2020). The results indicated that direct grafting on the Paulsen 1103 rootstock recorded the highest grafting success percentage. Moreover, the grafting success percentage increased significantly when Paulsen 1103 was used as interstock between Flame seedless and Freedom rootstock (Fl/P/Fr) compared to the grafting success without Paulsen 1103 interstock (Fl/Fr). Also, using Paulsen 1103 as interstock between Flame seedless scion and Freedom rootstock (Fl/P/Fr) significantly reduced the morphological parameters (shoot length, leaf area and the dry weight of shoots and roots) and physiological parameters of leaf (relative water content, transpiration rate, and stomatal conductance) but significantly increased the leaf chemical content (peroxidase activity, total phenols, total proline, and total soluble sugar content) compared to values of the parameters measured in Flame seedless grafted onto Freedom rootstock (Fl/Fr). Peroxidase activity could be used for predicting the degree of compatibility in grapevine grafts. This study suggested that the effect of Paulsen 1103 interstock on the vegetative growth of scion is correlated with its effect on chemical content and physiological responses of the scion.

Index terms: Leaf water content; stomatal conductance; transpiration rate; peroxidase; proline.

RESUMO

Enxerto intermediário é comumente utilizado em frutíferas decíduas como estratégia sustentável para reduzir o vigor do enxerto associada à alta qualidade dos frutos. Neste estudo, testamos o efeito de Paulsen 1103 (*Vitis berlandieri* x *Vitis rupestris*) como enxerto intermediário no sucesso da enxertia, crescimento e parâmetros fisiológicos e químicos de videira Flame seedless (*Vitis vinifera*) enxertada em Freedom (*Vitis champinii x 1613C*) e Paulsen 1103 porta-enxertos. Este estudo foi realizado ao longo de duas temporadas (2019 e 2020). Os resultados indicaram que a enxertia direta no porta-enxerto Paulsen 1103 registrou o maior percentual de sucesso da enxertia. Além disso, a porcentagem de sucesso de enxertia aumentou significativamente quando Paulsen 1103 foi usado como enxerto intermediário entre Flame seedless e Freedom (Fl/P/Fr) em comparação com o sucesso de enxertia sem o enxerto intermediário Paulsen 1103 (Fl/Fr). Além disso, usando Paulsen 1103 como enxerto intermediário entre copa de Flame sem sementes e o porta-enxerto Freedom (Fl/P/Fr) reduziu significativamente os parâmetros morfológicos (comprimento da parte aérea, área foliar e peso seco da parte aérea e das raízes), os parâmetros fisiológicos da folha (teor relativo de água , taxa de transpiração e condutância estomática), mas aumentou significativamente o conteúdo químico da folha (atividade de peroxidase, fenóis totais, prolina total e teor de açúcar solúvel total) em comparação com os valores dos parâmetros medidos em Flame sem sementes enxertados no porta-enxerto Freedom (Fl/Fr) . A atividade da peroxidase pode ser usada para prever o grau de compatibilidade em enxertos de videira. Este estudo sugeriu que o efeito do enxerto intermediário Paulsen 1103 no crescimento vegetativo do enxerto está correlacionado com seu efeito no conteúdo químico e nas respostas fisiológicas do enxerto.

Termos para indexação: Conteúdo água foliar; condução estomática; taxa transpiração; peroxidase; prolina.

INTRODUCTION

Grapevines (*Vitis vinifera*) are deciduous fruit-bearing vining plants cultivated around the world and cover 7.5 million hectares of land. They are used to produce wine, table grapes, and raisin grapes and have a large international economic return. They are produced the most in Spain, China, France, Italy, Turkey, and the United States of America (Food and Agriculture Organization - FAO, 2019).

Flame Seedless is a highly valuable red seedless grape cultivar from Egypt that ripens early and is widely exported (Lo'ay; El-khateeb, 2017). Many stresses, including those induced by nematodes, water, salinity, and others, negatively affect the productivity of Flame seedless vineyards in newly reclaimed semi-arid areas (El-Gendy, 2013). Grafting on resistant grapevine rootstock can overcome such problems (Reynolds; Wardle, 2001).

Grapevine rootstocks affect the grafting success or grafting compatibility of scion grapevines (Todic; Beslic; Kuljancic, 2005; Verma; Singh; Hare Krishna Patel, 2012; Vrsic; Pulko; Kocsis, 2015). The Flame seedless cultivar has higher grafting compatibility with the Paulsen 1103 rootstock compared to the Freedom rootstock, which has the lowest compatibility (Fayek et al., 2017). Also, Kamiloğlu and Guler (2014) and Teker, Ulas and Dolgun (2014) reported that the Paulsen 1103 rootstock recorded high grafting success and compatibility with grapevine cultivars (*Vitis vinifera*). Grapevine rootstocks influence vegetative growth, fruit quality, and vine productivity (Keller; Mills; Harbertson, 2012; El-Gendy, 2013). Freedom rootstock increases the vigor of the scion (Main; Morris; Striegler, 2002; Rizk-Alla; Sabry; Abd El-Wahab, 2011), while Paulsen rootstock decreases the vigor (Walker; Read; Blackmore, 2000; Keller; Mills; Harbertson, 2012). Paulsen rootstock can improve the fruit quality (physical and chemical characteristics) of Flame seedless and enhance the commercial value of grapes compared to the quality and value of the grapes grown using Freedom rootstock (Lo'ay; El-Khateeb, 2017; El-Banna; Lo'ay, 2019; Lo'ay; Doaa, 2020). Also, it has a positive effect on the color of wine grapes (Walker; Read; Blackmore, 2000).

Interstocks are used to overcome grafting incompatibility between the scion and the rootstock in many fruit trees (Rogers; Beakbane, 1957). Moreover, they can reduce the vigor of the scion, which is associated with high fruit quality and productivity; also, they can reduce the labor required (Koshita; Morinaga; Tsuchida, 2006). Additionally, the interstock can increase the tolerance of the scion to biotic stress (Erti; Agus, 2018; Shaltiel-Harpaz et al., 2018) and abiotic stress (Gimeno et al., 2012; Li et al., 2017). Beckman (2004) used the interstock to avoid spring freeze injury by modifying the bloom and harvest date of peach. In grapevine, the use of Paulsen 1103 as interstock within grafts improved the tolerance of the Flame seedless scion to drought (Fayek; Rashedy; Ali, 2022). The efficiency of the interstock depends on its length. A 10 cm-long interstock substantially affects the vigor of the scion of apple (Di Vaio et al., 2009), pear (Sosna; Kortylewska, 2013), and mango (Das; Dhakar, 2016). The interstock induces chemical and physiological changes in the scion. Fayek, Rashedy and Ali (2022) found that using Paulsen 1103 as interstock with the grafts of Flame seedless under drought stress increased the chemical content (proline, phenols, and total sugar content) in the leaves of the Flame seedless scion, which caused physiological and anatomical changes in the leaves of the Flame seedless scion. Zhao et al. (2016) reported that the dwarfing apple interstock increased the peroxidase activity and decreased the transpiration rate and stomatal conductance of the scion.

The effects of the interstock on the vegetative growth of grapevine have not been determined. The interstock might reduce the vine size or vegetative growth and thus, reduce the cost of managing the vine, which includes additional labor for vine training, pruning, and fruit thinning. Moreover, it might have beneficial effects on the quality of the fruit. Thus, using Paulsen 1103 as the interstock, we evaluated the performance of Flame seedless grapevine by determining the morphological, chemical, and physiological indices during its growth in the nursery.

MATERIAL AND METHODS

This study was conducted in two successive seasons (2019 and 2020) under shade-net greenhouse conditions at the nursery of the Pomology Department, Faculty of Agriculture, Cairo University at Giza. We determined the effects of Paulsen 1103 (*V. berlandieri* x *V. rupestris*) as the interstock on the performance of Flame seedless cv. (*Vitis vinifera*) grafted onto two rootstocks, which included Freedom (*V. champinii* x 1613C) and Paulsen 1103. The study site was located at 30°01'04"N latitude, 31°12'30"E longitude, and 30 m above the mean sea level.

Plant material

Flame seedless cv. cuttings (5 – 7 cm long; node + internode) were prepared as the scion. Freedom and Paulsen 1103 cuttings (25 cm long and 3 – 4 nodes) were prepared as rootstocks. Also, Paulsen 1103 interstock (10 cm long) was used as an intermediate piece between the Flame seedless scion and the two rootstocks (Freedom and Paulsen 1103). In January, all the hardwood cuttings of the plants were stored at 4 °C and 70% to 80% relative humidity for 30 days before grafting.

Grafting technique

Four grafting combinations were used, comprising Flame seedless grafted onto Freedom rootstock without Paulsen 1103 interstock (Fl/Fr), Flame seedless grafted onto Freedom with Paulsen 1103 interstock (Fl/P/Fr), Flame seedless grafted onto Paulsen 1103 rootstock without Paulsen 1103 interstock (FI/Pr), and Flame seedless grafted onto Paulsen 1103 rootstock with Paulsen 1103 interstock (FI/P/Pr). Grafting was performed using the tongue graft technique during the first week of February. We used 45 grafts for each combination representing three replicates. The grafted areas were covered (rolled and tied) with special plastic parafilm and dipped for 1 s in hot grafting-wax paraffin. The cutting bases of the rootstocks were dipped in indole-3-butyric acid (2,000 ppm) for 5 s. The grafted materials were placed in plastic boxes in layers mixed with a wet mixture of peat and sawdust (1:4 v/v), covered with a polyethylene sheet, and incubated for 30 days in an incubation room at 28 °C and 90% RH for callus formation (Paunović et al., 2012).

Planting in nursery and growth conditions

After incubation, the graft combinations (FI/Fr, FI/P/Fr, FI/Pr, and FI/P/Pr) were transferred to a shade-net greenhouse (shade rating of 40%). The grafts were planted in 10 L black plastic pots (30 × 30) filled with washed sandy soil in a plastic tunnel and grown for one month before being removed on 1st April. The physical and chemical analyses of the soil and irrigation water are presented in Table 1. The pots were irrigated every two days until complete saturation or leaching (100% field capacity) with tap water using a drip irrigation system (4 L/h). The efficiency of the leaching process was checked and bricks were placed under the pots to prevent the roots from spreading out of the pots. The grafts were pruned by removing the lateral shoot to maintain the plants with a single main shoot that was supported with wood sticks and two horizontally placed trellis wires with a vertical gap of 30 cm between them. These wires kept the saplings off the ground, increased their exposure to the sun, and made it easier to take measurements and collect samples to be further processed in the laboratory. During the experiment, macronutrients and micronutrients were added by applying the Hoagland nutrient solution at a weekly rate of 0.25 strength via drip irrigation (Fozouni; Abbaspour; Banch, 2012). Pests were controlled by spraying pesticides at recommended concentrations only during the critical period of pest activity.

Morphological parameters

Grafting success percentage was calculated using the following equation: (Total number of successes grafts/ Total number of the grafts) x 100.

Callus degree was assessed at the grafting union after 30 days of incubation as described by Çelik (2000). Also, some parameters were measured at the end of the experiment (1st September), including shoot length (cm), the number of leaves, leaf area (cm^2), shoot dry weight (g), and root dry weight (g). Leaf area was calculated following the method described by Khan et al. (2016) from the shoot apex to the seventh mature leaf using the following equation: $LA = 0.465 + 0.914 * W * L$.

Here, W indicates the leaf width (cm) and L indicates the leaf length.

Physiological parameters

At the end of the experiment, several physiological parameters were measured on the seventh mature leaf from the shoot apex. The transpiration rate (µg $H_2O/cm^2/s$) and stomatal conductance (cm/s) were determined using a portable steady-state porometer (LI-1600M, LI-COR, Nebraska, USA) between 10:00 am and 12:00 pm following the method described by Surendar et al. (2013). The relative water content (RWC) was calculated using the following formula: [(FW-DW)/(TW-DW)/(FW-DW) x 100]

Table 1: Soil and water sample analysis.

Soil sample analysis														
Physical characteristics				Chemical characteristics										
				Cation (mM/L)						Anion (Mm/L)				
Sand	Silt	Clay	Soil texture	EC (dS/m)	pH	$CaCO_3$%	Ca^{2+}	Mg^{2+}	K^+	Na^+	$(SO_4)^{2-}$	Cl^-	$(HCO_3)^-$	$(CO_3)^{2-}$
85.8%	11.2%	3%	Sandy soil	1.21	7.91	4.9%	3.8	1.9	0.3	60	1.63	10	0.37	-

Water samples analysis									
Cation (mM/L)						Anion (Mm/L)			
EC (dS/m)	pH	Ca^{2+}	Mg^{2+}	K^+	Na^+	Cl^-	$(SO_4)^{2-}$	$(HCO_3)^-$	$(CO_3)^{2-}$
0.48	7.53	2.3	1.4	0.18	0.84	2.5	0.42	1.8	-

Here, FW indicates the fresh weight (g), TW indicates the turgid weight (g), and DW indicates the dry weight (g) (Medeiros et al., 2012).

Biochemical analysis

A sample (0.5 g FW) of the seventh leaf from the shoot apex was used for the following chemical analysis at the end of the experiment (1st September). Peroxidase activity (mg/g FW) was determined according to previous studies (Hammerschmidt; Nuckles; Kuc, 1982; Ni et al., 2001). Total phenols (mg/g FW) were determined according to the Folin-Ciocalteu method (Mng'omba; Du Toit; Akinnifesi, 2008). Free proline content (µm/g) was determined following the method described by Bates, Waldren and Teare (1973). Total soluble sugars (mg/g FW) were determined based on the phenol-sulfuric acid method (Dubois et al., 1956).

Statistical analysis

This experiment included the interaction between two grapevine rootstocks and the presence or absence of interstock, comprising four treatments. The experiment had a randomized complete block design with three replicates per treatment and 15 grafts in each replicate. Analysis of variance (ANOVA) was performed to analyze the data using the MSTAT pocket program. The least significant difference (LSD) was used to compare the means of the treatments, and statistical significance was determined at $p < 0.05$ (Duncan, 1955).

RESULTS AND DISCUSSION

Grafting success and callus degree

Rootstocks and interstocks significantly affected grafting success percentage and callus degree (Figure 1) at grafting union ($p < 0.05$). Grafting of the Flame seedless scion on Paulsen 1103 rootstock (FI/Pr) recorded the highest significant values for grafting success percentage (66.66%) and callus degree (3.00) compared to the values of these parameters measured in Flame seedless grafted onto Freedom rootstock (FI/Fr), which showed the lowest values for grafting success percentage (43.33%) and callus degree (2.58). Paulsen 1103 rootstock had the highest grafting success and compatibility with grapevine cultivars (*Vitis vinifera*) in several studies (Kamiloğlu; Guler, 2014; Teker; Ulas; Dolgun, 2014). Fayek et al. (2017) found that higher values for callus degree at grafting union and grafting success percentage of Flame seedless scion were recorded for grafting with the Paulsen 1103 rootstock compared to the values of these parameters measured with the Freedom rootstock. Moreover, using Paulsen 1103 as the interstock between Flame seedless scion and Freedom rootstock (FI/P/Fr) significantly improved grafting success percentage (55.00%) and callus degree at grafting union (2.83) compared to the values of the parameters measured in Flame seedless grafted onto Freedom without the Paulsen 1103 interstock (FI/Fr). These findings were similar to those of the studies by Girardi and Filho (2006) (citrus), Sosna and Kortylewska (2013) (pear), and Calderón, Weibel and Trentacoste (2021) (peach). These studies found that using the interstock improved grafting success and the compatibility between the scion and the rootstock. We found that the Paulsen 1103 rootstock can be used as an interstock to improve grafting success in the grapevine. This might be due to highly similar isoperoxidase enzymes in Paulsen 1103 and the scion of Flame seedless (Fayek et al., 2017). Also, Balbi et al. (2019) reported that the interstock of EMA pear improved the anatomical characteristics following the grafting union between pear cultivars and quince rootstock.

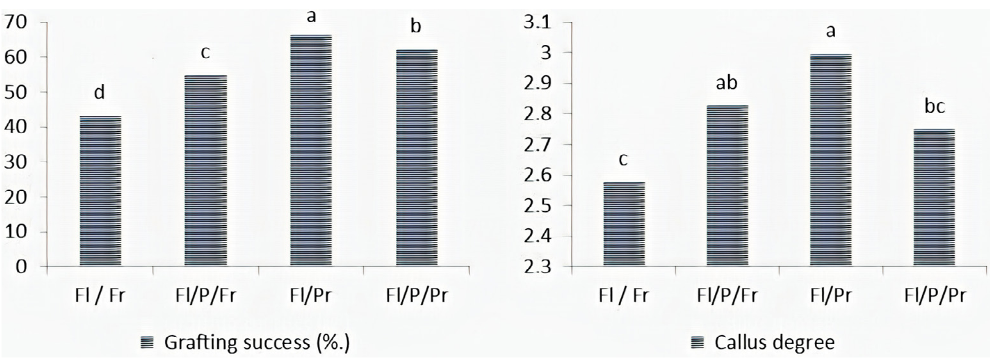

Figure 1: The effect of the rootstock and interstock on grafting success percentage and callus degree at grafting union of the Flame seedless scion (season 2019). Fl/Fr: Flame seedless grafted onto Freedom rootstock, Fl/P/Fr: Flame seedless grafted onto Freedom rootstock with Paulsen as interstock, Fl/Pr: Flame seedless grafted onto Paulsen rootstock, and Fl/P/Pr: Flame seedless grafted onto Paulsen rootstock with Paulsen as interstock. The letters represent significant differences at the 5% level LSD.

Morphological parameters

Grafting of Flame seedless on Freedom rootstock (Fl/Fr) significantly increased several parameters related to vegetative growth compared to the values of the parameters measured in Flame seedless grafted onto Paulsen 1103 rootstock (Fl/Pr). These parameters included the shoot length (66.733 cm & 80.833 cm) and the root dry weight (31.857 g & 30.940 g) through the first and second harvest, respectively, besides the leaf area (140.610 cm^2) in the first season. Previous studies on grapevine found that the vegetative growth of the scion was affected by the type of rootstock used in grafting (Walker; Read; Blackmore, 2000; Keller; Mills; Harbertson, 2012). Our results were similar to those reported by Rizk-Alla, Sabry, and Abd El-Wahab (2011), who found that the vigor of the scions was higher with Freedom rootstock than with Paulsen 1103 rootstock. Also, Hifny et al. (2016) reported that the highest rate of shoot growth was recorded with Red Globe grafted onto Freedom rootstock. This might be due to the variation in the efficiency of the rootstock associated with water and nutrient uptake (El-Gendy, 2013; Verdugo-Vásquez et al., 2021). Furthermore, using Paulsen interstock while grafting Flame seedless grafts onto Freedom (Fl/P/Fr) significantly decreased the shoot length (54.750 cm & 70.377 cm) and root dry weight (15.013 g & 25.490 g) in both seasons, besides decreasing the leaf area (101.010 cm^2) in the first season, compared to the values of these parameters measured in Flame seedless grafted onto Freedom without the Paulsen 1103 interstock (Fl/Fr). This effect might be caused by the obstruction of the interstock during water transport to the shoots, resulting in a decrease in gas exchange, photosynthetic capacity, and photoassimilate transport to the roots. This might cause poor root growth, thus limiting the uptake of minerals and water (Zhao et al., 2016; Zhou et al., 2021).

Physiological parameters

The results (Figure 2) indicated that grafting on Freedom rootstock increased the leaf water content, transpiration rate, and stomatal conductance of scion leaves, which was related to an increase in the morphological parameters (Table 2) compared to grafting on Paulsen 1103 rootstock. Previous studies have also shown that grapevine rootstocks affect the water status, transpiration rate, and stomatal conductance of scion leaves, which are related to the vegetative growth of the vine (Soar; Dry; Loveys, 2006; Satisha; Ramteke; Karibasappa, 2007; Koundouras et al., 2008; Verma; Singh; Krishna, 2010; Tramontini et al., 2013; Ghule et al., 2019). Using Paulsen 1103 as the interstock while grafting Flame seedless on Freedom rootstock (Fl/P/Fr) significantly decreased the relative water content (45.357%), transpiration rate (1.503 µg $H_2O/cm^2.s$), and stomatal conductance (0.060 cm/s) of scion leaves, which were related to the lowest values of the morphological parameters (Table 2), compared to the values of the parameters measured in Flame seedless grafted onto Freedom without an interstock (Fl/Fr). These results were similar to those found by Fayek, Rashedy and Ali (2022), who reported that the Paulsen interstock caused changes in physiological parameters, such as the relative water content, transpiration rate, and stomatal conductance of the leaves of the scion grapevine. This effect might be due to the obstruction of water transport to the shoots by the interstock, which led to a reduction in the stomata and reduced the entry of CO_2 and light into the leaf (Zhou et al., 2015; Zhao et al., 2016).

Biochemical analysis

The results indicated that rootstocks and interstocks significantly increased the chemical content in the scion leaves of Flame seedless (Table 3). Previous studies reported that the chemical content of scion was affected by the type of rootstock used for grafting (Jogaiah et al., 2013; Köse; Karabulut; Ceylan, 2014; Souza et al., 2015; Da Silva et al., 2017). In this study, the results suggested that grafting Flame seedless onto Paulsen 1103 rootstock (Fl/Pr) significantly increased the peroxidase activity (10.297 & 12.650 mg/g FW) and proline content (1.167 µm/g FW & 1.933 µm/g FW) in both seasons, besides increasing the total phenols and total soluble sugars, compared to the values of these parameters measured in Flame seedless grafted onto Freedom rootstock (Fl/Fr). The findings were similar to those reported in a study by Satisha, Ramteke, and Karibasappa (2007), who found that the Paulsen 1103 rootstock recorded the highest values of the total phenols, proline, and total soluble sugar content in the leaf. Also, Somkuwar et al. (2014) found that the Rchiter 110 rootstock grapevine recorded the highest total phenols and total soluble sugar content in the leaves of the Thompson seedless scion, and the lowest values for vegetative growth parameters compared to the values of the parameters measured for the Dog Ridge rootstock. Also, using Paulsen 1103 as the interstock for the grafting of Flame seedless onto Freedom (Fl/P/Fr) increased the peroxidase activity, phenols, and proline content, besides increasing the total

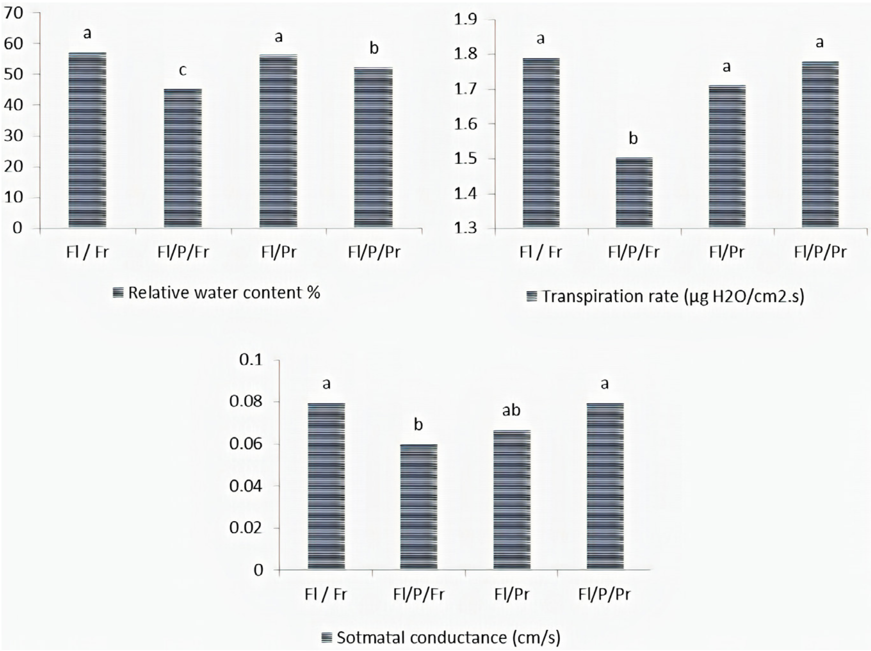

Figure 2: The effect of the rootstock and interstock on physiological parameters of the Flame seedless scion. Fl/Fr: Flame seedless grafted onto Freedom rootstock, Fl/P/Fr: Flame seedless grafted onto Freedom rootstock with Paulsen as interstock, Fl/Pr: Flame seedless grafted onto Paulsen rootstock, Fl/P/Pr: Flame seedless grafted onto Paulsen rootstock with Paulsen as interstock. The letters represent significant differences at the 5% level LSD.

Table 2: The effect of the rootstock and interstock on the morphological parameters of the Flame seedless scion.

	Rootstocks (A)	First season			Second season		
		Interstock (B)		Mean	Interstock (B)		Mean
		Without	With		Without	With	
Shoot length (cm)	Freedom	66.733 a	54.750 c	60.742 A	80.833 a	70.377 c	75.605 A
	Paulsen 1103	61.100 b	45.493 d	53.297 B	74.500 b	50.127 d	62.313 B
	Mean	63.917 A	50.122 B		77.677 A	60.252 B	
Leaf number (n)	Freedom	36.887 a	37.130 a	37.008 A	33.890 a	31.663 a	32.777 A
	Paulsen 1103	33.830 a	30.550 b	32.190 B	33.887 a	32.110 a	32.998 A
	Mean	35.359 A	33.840 B		33.888 A	31.887 B	
Leaf area (cm^2)	Freedom	140.610 a	101.010 c	118.295A	85.010 a	74.957 a	79.984 A
	Paulsen 1103	120.200 b	95.367 d	107.450B	80.580 a	69.930 a	75.255 A
	Mean	130.405 A	98.188 B		82.795 A	72.443 B	
Shoot dry weight (g)	Freedom	12.703 a	8.940 a	10.822 A	17.530 a	11.143 a	14.337 A
	Paulsen 1103	11.803 a	7.807 a	9.805 A	13.933 a	10.030 a	11.982 B
	Mean	12.253 A	8.373 B		15.732 A	10.587 B	
Root dry weight (g)	Freedom	31.857 a	15.013 c	23.435 A	30.940 a	25.490 b	28.215 A
	Paulsen 1103	26.883 b	16.367 c	21.625 B	26.957 b	26.980 b	26.968 A
	Mean	29.370 A	15.690 B		28.948 A	26.235 B	

The mean for each parameter in each season with the same letter was not significantly different at the 5% level LSD.

soluble sugar content, which was related to the lowest values of the tested morphological parameters (Table 2), compared to the values of the parameters measured in Flame seedless grafted onto Freedom rootstock without an interstock (FI/Fr). Similarly, Fayek, Rashedy and Ali (2022) found that the Paulsen grapevine interstock under drought stress increased the total soluble sugar, phenols, and proline content of the Flame seedless scion. The increase in the chemical content in scions when using interstock might be due to the particle limiting effect of the interstock on the transport of the photosynthetic products to the roots; these products accumulated in the scion (Zhou et al., 2021). Zhao et al. (2016) reported that high levels of peroxidase activity increased the oxidation of indole-3-acetic acid in the shoots and reduced the synthesis of cytokinin and gibberellin in the roots. This might explain the negative relationship between an increase in the peroxidase activity and a reduction in the tested morphological parameters (Table 2) when using Paulsen 1103 as the interstock. The grafting success of Flame seedless on Paulsen either as rootstock (Fl/Pr) or interstock (Fl/P/Fr) was higher than that for grafting with Freedom rootstock (Fl/Fr) (Figure 1). Additionally, this was associated with higher peroxidase activity while using Paulsen (Table 3). Thus, the peroxidase activity test might be used to predict the degree of compatibility in grapevine grafts.

CONCLUSIONS

Paulsen 1103, when used as the interstock, improved grafting success between the Flame seedless grapevine and the Freedom rootstock. It also reduced the vegetative growth of Flame seedless, which was accompanied by a decrease in the physiological parameters of the leaves such as the relative water content, transpiration rate, and stomatal conductance, and an increase in the chemical content of the leaves such as the content of proline, total sugars, and phenol in the scion.

AUTHOR CONTRIBUTIONS

Conceptual Idea: Fayek, M.A.; Rashedy, A.A.; Methodology design: Fayek, M.A.; Rashedy, A.A.; Ali, A.E.M.; Data collection: Ali, A.E.M.; Data analysis and interpretation: Fayek, M.A.; Rashedy, A.A.; Ali, A.E.M.; Writing and editing: Fayek, M.A.; Rashedy, A.A.; Ali, A.E.M.

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Table 3: The effect of the rootstock and interstock on the chemical content of the Flame seedless scion.

	Rootstocks (A)	First season			Second season		
		Interstock (B)		Mean	Interstock (B)		Mean
		Without	With		Without	With	
Peroxidase activity (mg/g FW)	Freedom	9.500 d	9.967 c	9.733 B	12.100 c	13.167 a	12.633 B
	Paulsen 1103	10.297 b	13.150 a	11.723 A	12.650 b	13.067 a	12.858 A
	Mean	9.898 B	11.558 A		12.375 B	13.117 A	
Total phenols content (mg/g FW)	Freedom	6.157 c	7.440 b	6.798 B	9.727 c	10.263 b	9.995 B
	Paulsen 1103	6.350 c	8.550 a	7.450 A	9.807 c	10.653a	10.230 A
	Mean	6.254 B	7.995 A		9.767 B	10.458 A	
Total Proline content (µm/g FW)	Freedom	0.750 c	0.950 b	0.850 B	1.733 b	1.900 a	1.817 A
	Paulsen 1103	1.167 a	0.933 b	1.050 A	1.933 a	1.500 c	1.717 A
	Mean	0.958 A	0.942 A		1.833 A	1.700 B	
Total sugar content (mg/g FW)	Freedom	9.557 a	10.080 a	9.818 B	11.697 b	11.797ab	11.747A
	Paulsen 1103	10.763 a	11.437 a	11.100 A	11.877 a	11.783ab	11.830 A
	Mean	10.160 B	10.758 A		11.787 A	11.790 A	

The mean for each parameter in each season with the same letter was not significantly different at the 5% level LSD.

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