



Drought-stress tolerance potential in plum and prune rootstocks and cultivars (*Prunus* spp.) based on physiological and photosynthetic parameters

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Received: 17 September 2023; Accepted: 18 July 2024

ABSTRACT

Drought stress and water crisis is a great limiting factor for the production of horticultural crops. The present study was carried out during 2021 and 2022 at Horticultural Science Research Institute, Kamalshahr, Karaj, Iran to identify the effect of drought stress in physiological and photosynthetic characteristics of *Prunus* spp. rootstocks and varieties of 4-year old *Prunus* spp. The factorial experiment was conducted in a completely randomized block design (CRBD) having 3 factors and 3 replications. Factors included 8 rootstocks, viz. Myrobalan 29C, Penta, Tetra, St. Julien, Mariana 2624, GF 677, GN 15 and Seedling as the first factor; 4 cultivars, viz. Greengage, Simka, NO 16 and Zochelo as the second factor; and drought stress conditions in two levels namely with interruption of irrigation for 14 days and without interruption of irrigation as the third factor. Drought stress decreased relative water content of leaves, stomatal conductance, transpiration, CO₂ content in substomatal chamber, and water use efficiency. Zuchelo and Greengage varieties and GN 15 rootstock had the highest and Simka variety and Mariana 2624 and Myrobalan 29C rootstocks had the lowest stomatal exchanges and photosynthesis, respectively. Among the rootstocks; GN 15, GF 677 and Mariana 2624 showed better physiological stability under stress, and the most tolerant variety against drought stress was NO 16. Totally, grafting combination of cv. NO 16 and rootstock GN 15 has been identified as the most tolerant to drought stress.

Keywords: Drought tolerance, Fruit plants, Rosaceae family, Water deficit

Plums (*Prunus* spp.) are one of the most important crops and the most diverse group of stone fruits in temperate regions (Martínez-García *et al.* 2020). The plum has been used worldwide both as a genetic source for breeding new rootstocks and as clonal rootstock for many *Prunus* spp. (Korkmaz *et al.* 2023). Drought stress is one of the main abiotic stresses worldwide that negatively affects crops' metabolism, growth, and yield (Blaya-Ros *et al.* 2021). The adaptive responses of plants to drought can be morphological, physiological, or biochemical. The use of new tolerant/resistant cultivars and rootstocks is a necessary aim in *Prunus* breeding (Martínez-García *et al.* 2020, Korkmaz *et al.* 2023). Identification of drought-resistant plant genotypes help to increase the efficiency of plants under drought stress. The relative water content of leaf, stomatal conductance, transpiration rate and canopy temperature are important characteristics that are affected by water relations (Atashkar *et al.* 2019). Martínez-García

et al. (2020) revealed that all physiological traits of *Prunus* spp. associated with photosynthetic activity, leaf water status and chlorophyll content were negatively affected by drought. During evaluation of the effect of drought stress on the physiological characteristics of some almond cultivars, the role of genotype in drought resistance was evaluated positively (Akbarpour and Imani 2016). The growth and biochemical responses of some almond cultivars on GN 15 rootstock showed that Sahand and Franis almond cultivars had higher tolerance to drought stress compared to other genotypes (Fathi *et al.* 2017). Almond spp., with a special morphology and historical tolerance showed the best drought tolerance compared to the other *Prunus* spp. such as apricot and peach (Martínez-García *et al.* 2020). Due to the limitation of water resources, identifying rootstocks and cultivars tolerant to drought stress is important. Therefore, the present study was undertaken to identify drought-stress rootstocks and varieties of plums based on photosynthetic and physiological characteristics.

MATERIALS AND METHODS

Present study was carried out during 2021 and 2022 (two seasons) at Horticultural Science Research Institute, Kamalshahr, Karaj, Iran. The factorial experiment was conducted in a completely randomized block design (CRBD)

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having 3 factors with 3 replications. Factors included rootstocks as the first factor in 7 levels (Myrobalan 29C, Penta, Tetra, St. Julien, Mariana 2624, GF 677, GN 15 and Seedling); cultivars as the second factor in 4 levels (Greengage as Shahryar plum and prune, Simka and NO 16 as Japanese plum and prune and Zochelo as European plum and prune); and drought stress conditions as the third factor in 2 levels (with interruption of irrigation for 14 days and without interruption of irrigation). The stress (stop irrigation) was applied in August for 14 days as compared to control (irrigated). Four cultivars were evaluated on eight rootstocks with three replications at two levels: drought stress and control on a total of 192 trees with the age of 4 years.

To determine the relative water content of leaf, pieces of the leaf were selected and their fresh weight was determined. The leaf pieces are placed in distilled water for 24 h at low light intensity and temperature of 4°C until the cells inside the leaf absorb water and become turgid. The turgid pieces were weighed again. Then, the leaves were dried at 75°C for 24 h and their dry weight was measured. The relative water content of leaf was obtained as (Kirk et al. 2001):

$$\text{Relative water content of leaf (\%)} = \frac{W_f - W_d}{W_t - W_d} \times 100$$

where W_f Leaf fresh weight; W_d , Leaf dry weight; and W_t , Leaf weight in turgid condition.

To measure the ion leakage, an equal amount of the leaves in each replication were transferred into test tubes containing 10 ml of sterile distilled water. Solution was placed on a shaker for 24 h at laboratory temperature for ready to measure the initial electrical conductance. The electrical conductance of the samples was read with a digital EC-meter. In the next step, the test tubes containing the samples were placed in a water bath at 100°C for 20 min from the time of boiling, and after the tubes were cooled, the electrical conductance of the samples was measured

again. Finally, the ion leakage percentage was obtained as (Zhao et al. 1992):

$$\text{Ion leakage (\%)} = \frac{EL1}{EL2} \times 100$$

where EL1 and EL2 are primary and secondary electrical conductance, respectively.

Canopy temperature, stomatal conductance, transpiration, photosynthesis and substomatal CO_2 were measured and calculated using a photosynthesis-meter (LCI model, UK-ABC Company) on sunny days (from 11:00–13:00). The sampling time was September–October. Samples (adult leaves) were randomly taken from all parts of a tree (different and median branches) and the average was taken. Water use efficiency (dividing photosynthesis by transpiration) and mesophyll conductive (dividing the amount of photosynthesis by the amount of substomatal CO_2) were obtained by methods presented by Fischer et al. (1998).

Analysis of variance of the data was done using Minitab 17 software, and SPSS software was used for correlation analysis using Varimax method. Averages were compared using Duncan's test at the 5% level of significance.

RESULTS AND DISCUSSION

The cultivars Simka and Greengage had the highest relative water content of leaf (59.47 and 61.27%), respectively (Table 1). In the comparison between the rootstocks, Mariana 2624 had the highest content of water (61.56) (Table 2). Obtained results related to the triple interaction effect on relative water content showed that the highest value (78.04%) was obtained in NO 16 and Mariana 2624 grown under stress condition (Table 3). The interaction effect of Greengage and Mariana 2624 under drought-stress condition, as well Simka and GN 15 under control condition also had a high relative water content similar to the treatment of Mariana 2624 and NO 16 under

Table 1 The main effect of cultivars on the physiological characteristics of plum and prune

Cultivar	Relative water content (%)		Canopy temperature (°C)		Substomatal CO_2 (mM)		Transpiration (mM $H_2O/m^2/s$)	
	Stress	Control	Stress	Control	Stress	Control	Stress	Control
Greengage	61.27 ^a	57.78 ^a	37.27 ^b	38.21 ^a	226 ^b	217 ^d	7.00 ^c	8.99 ^a
NO 16	52.31 ^b	52.73 ^b	38.84 ^a	38.13 ^a	232 ^b	239 ^c	8.02 ^{ab}	7.69 ^b
Simka	59.47 ^a	57.97 ^a	37.98 ^{ab}	37.87 ^a	258 ^a	250 ^b	7.40 ^{bc}	7.68 ^b
Zuchelo	46.70 ^c	50.63 ^c	35.89 ^c	34.62 ^b	255 ^a	263 ^a	8.14 ^a	7.03 ^c
Cultivar	Photosynthesis (mM $CO_2/m^2/s$)		Ion leakage (%)		Water use efficiency (kg/m ³)		Stomatal conductance (mM/m ² /s)	
	Stress	Control	Stress	Control	Stress	Control	Stress	Control
Greengage	11.82 ^b	17.42 ^a	38.98 ^{ab}	39.38 ^{ab}	1.59 ^b	1.89 ^a	0.19 ^c	0.26 ^b
NO 16	12.38 ^b	11.12 ^c	33.44 ^b	32.52 ^c	1.36 ^c	1.45 ^b	0.25 ^b	0.21 ^c
Simka	10.62 ^{bc}	13.17 ^{bc}	37.65 ^{ab}	44.68 ^a	1.59 ^b	1.72 ^{ab}	0.20 ^c	0.25 ^b
Zuchelo	16.51 ^a	15.49 ^b	42.42 ^a	45.65 ^a	1.97 ^a	1.97 ^a	0.33 ^a	0.38 ^a

Means with similar letters in each column are not significantly different at 5% probably level (Duncan's Multiple Range Test).

stress condition (Table 3).

The reduction of the relative content or water potential of leaves under drought stress has been reported in many plants (Martínez-García *et al.* 2020). The investigations done on apple showed that the reduction of the relative water content of leaf is not the same in different cultivars (Atkinson *et al.* 2000). Probably, these cultivars and rootstocks have the ability to absorb more water from the soil, or their intracellular osmolytes led to an increase in the relative water content of leaf in them. This finding was similar to our finding.

Among the cultivars, the highest and lowest ion leakage (45.65 and 32.52%) were obtained in Zuchelo and NO 16, respectively, both under control condition (Table 1). NO 16 had lower ion leakage (33.34%), even under stress condition. On the other hand, among the rootstocks, the highest and lowest ion leakage (46.46 and 31.37%) were measured in Seedling (under stress condition) and Tetra (under control condition), respectively (Table 2). Evaluation of the interaction effect of rootstock and variety on the trait of ion leakage rate showed that the maximum values (59.87 and 59.86%) were measured in GF 677 + Greengage + control and GN 15 + Greengage + control, respectively (Table 3). On the other hand, the minimum value (19.79%) was measured in NO 16 + St. Julien + control (Table 3).

Results showed that NO 16 had the highest relative water content of leaf and the lowest ion leakage percentage. One important reason for this resistance could be the shoot morphology of this cultivar. The developed osmotic adjustment during the greater part of the stress period, seems

to help some cultivars to survive in drought conditions (Martínez-García *et al.* 2020). Leakage of electrolytes is related to the preservation and integrity of the cell membrane under drought stress. In dry stress conditions, the cell membrane undergoes structural damage due to the peroxidation of lipids as a result of the accumulation of reactive oxygen species (ROS). The mentioned rootstocks and cultivars had the ability to stabilize the cell membrane and can protect the cell membrane against stress similar to the control conditions (Martínez-García *et al.* 2020).

The highest and lowest internal canopy temperature (38.84 and 34.62°C) in cultivars belonged to NO 16 in stress condition and Zuchelo in control condition, respectively (Table 1). In rootstocks, Mariana 2624 in stress condition and GN 15 in control condition had the highest (38.61°C) and lowest (36.12°C) canopy temperature, respectively (Table 2). Totally, the highest (40.20°C) canopy temperature was measured in two treatments (Zuchelo + GF 677 + control and Simka + Mariana 2624 + control). On the other hand, the lowest temperature (32.31°C) was measured in Zuchelo + Tetra + control (Table 3).

The highest and lowest accumulation of substomatal CO₂ (263 and 217 mM) belonged to Zuchelo and Greengage both in control condition, respectively (Table 1). The highest accumulation of CO₂ in rootstocks (267 mM) was measured in Penta in stress condition (Table 2). Simka + Penta in stress condition and Greengage + GN 15 in control condition had the highest (349 mM) and the lowest (119 mM) of substomatal CO₂ (Table 3).

Drought stress affects the plant physiological and

Table 2 The main effect of rootstocks on the physiological characteristics of plum and prune

Rootstock	Relative water content (%)		Canopy temperature (°C)		Substomatal CO ₂ (mM)		Transpiration (mM H ₂ O/m ² /s)	
	Stress	Control	Stress	Control	Stress	Control	Stress	Control
GF 677	52.93 ^{cd}	53.73 ^{bc}	37.33 ^{ab}	38.10 ^a	250 ^b	259 ^a	8.85 ^a	7.79 ^b
GN 15	53.13 ^{cd}	54.85 ^b	37.50 ^{ab}	36.12 ^c	243 ^{bc}	225 ^c	7.28 ^{bc}	6.81 ^c
Tetra	53.06 ^{cd}	54.67 ^b	37.51 ^{ab}	37.07 ^{a-c}	237 ^{cd}	237 ^{bc}	8.04 ^{ab}	8.06 ^{ab}
Penta	54.48 ^{b-d}	55.13 ^b	37.00 ^b	36.50 ^{bc}	267 ^a	254 ^a	7.58 ^{bc}	8.15 ^{ab}
St. Julien	56.20 ^b	58.78 ^a	37.50 ^{ab}	37.51 ^{a-c}	230 ^{de}	227 ^{bc}	6.97 ^c	8.36 ^{ab}
Myrobalan 29C	55.51 ^{bc}	51.21 ^d	37.65 ^{ab}	37.10 ^{a-c}	240 ^{b-d}	240 ^b	7.38 ^{bc}	6.84 ^c
Mariana 2624	61.56 ^a	57.72 ^a	38.61 ^a	37.80 ^{ab}	225 ^e	233 ^{bc}	7.71 ^{bc}	8.74 ^a
Seedling	52.64 ^d	52.14 ^{cd}	36.90 ^b	37.40 ^{a-c}	251 ^b	261 ^a	7.30 ^{bc}	8.03 ^{ab}
Rootstock	Photosynthesis (mM CO ₂ /m ² /s)		Ion leakage (%)		Water use efficiency (kg/m ³)		Stomatal conductance (mM/m ² /s)	
	Stress	Control	Stress	Control	Stress	Control	Stress	Control
GF 677	11.24 ^c	12.72 ^{cd}	42.13 ^{ab}	45.35 ^a	1.59 ^{bc}	1.65 ^b	0.31 ^a	0.17 ^c
GN 15	16.76 ^a	13.81 ^c	34.02 ^c	42.72 ^{ab}	1.87 ^a	1.63 ^b	0.24 ^c	0.41 ^a
Tetra	12.65 ^{bc}	13.51 ^c	36.26 ^{bc}	31.37 ^c	1.55 ^{bc}	1.78 ^{ab}	0.24 ^c	0.25 ^d
Penta	10.42 ^{cd}	15.35 ^b	37.67 ^{bc}	34.94 ^{bc}	1.25 ^{cd}	1.87 ^a	0.22 ^{de}	0.29 ^b
St. Julien	12.48 ^{bc}	14.93 ^{bc}	36.76 ^{bc}	38.50 ^b	1.73 ^{ab}	1.77 ^{ab}	0.20 ^f	0.27 ^c
Myrobalan 29C	9.97 ^d	12.56 ^{cd}	32.55 ^{cd}	41.81 ^{ab}	1.68 ^b	1.63 ^b	0.22 ^{ef}	0.24 ^d
Mariana 2624	13.64 ^b	17.55 ^a	38.00 ^b	35.65 ^{bc}	1.49 ^c	1.90 ^a	0.28 ^b	0.29 ^b
Seedling	15.49 ^{ab}	13.97 ^c	46.46 ^a	31.94 ^c	1.87 ^a	1.83 ^a	0.23 ^{cd}	0.29 ^b

Means with similar letters in each column are not significantly different at 5% probably level (Duncan's Multiple Range Test).

Table 3 The mean comparison of interaction effect of rootstocks and cultivars on the physiological characteristics of plum and prune

Cultivar	Rootstock	Relative water content (%)		Canopy temperature (°C)		Substomatal CO ₂ (mM)		Transpiration (mM H ₂ O/m ² /s)	
		Stress	Control	Stress	Control	Stress	Control	Stress	Control
Zuchelo	GF 677	43.90 ^{cd}	60.04 ^a	36.03 ^a	40.20 ^a	266 ^{a-c}	223 ^c	8.55 ^a	9.36 ^a
	GN 15	47.91 ^b	37.51 ^e	35.00 ^a	33.00 ^{bc}	254 ^{a-d}	284 ^a	8.28 ^a	3.23 ^e
	Tetra	43.80 ^{cd}	48.65 ^{cd}	35.80 ^a	32.31 ^c	232 ^d	249 ^{bc}	8.08 ^a	6.15 ^d
	Penta	41.06 ^d	45.40 ^d	36.10 ^a	33.10 ^{bc}	247 ^{b-d}	286 ^a	8.02 ^a	7.31 ^{bc}
	St. Julien	51.90 ^a	54.70 ^b	36.30 ^a	35.90 ^b	244 ^{cd}	253 ^b	8.53 ^a	8.16 ^b
	Myrobalan 29C	46.80 ^{bc}	47.50 ^{cd}	36.40 ^a	34.10 ^b	276 ^a	275 ^{ab}	8.33 ^a	7.41 ^{bc}
	Mariana 2624	51.70 ^a	59.84 ^a	37.30 ^a	34.35 ^{ab}	253 ^{a-d}	255 ^b	8.23 ^a	7.46 ^{bc}
	Seedling	46.60 ^{bc}	51.45 ^{bc}	34.20 ^a	33.94 ^b	274 ^{ab}	282 ^a	7.13 ^b	7.18 ^c
Greengage	GF 677	57.40 ^{cd}	38.98 ^d	37.20 ^{ab}	37.70 ^{ab}	254 ^b	237 ^c	9.13 ^a	8.25 ^{ab}
	GN 15	56.70 ^{cd}	52.26 ^c	37.80 ^{ab}	36.80 ^b	194 ^d	119 ^g	6.36 ^{a-c}	8.02 ^b
	Tetra	62.80 ^{bc}	51.64 ^c	37.33 ^{ab}	39.80 ^a	239 ^{ab}	235 ^d	7.14 ^{a-c}	10.70 ^a
	Penta	59.29 ^{cd}	67.05 ^a	35.00 ^b	37.60 ^{ab}	231 ^{bc}	246 ^b	6.78 ^{a-c}	9.27 ^{ab}
	St. Julien	62.20 ^{bc}	63.39 ^a	37.10 ^{ab}	37.90 ^{ab}	222 ^{bc}	182 ^f	6.83 ^{a-c}	8.36 ^{ab}
	Myrobalan 29C	66.70 ^{ab}	58.25 ^b	37.30 ^{ab}	38.00 ^{ab}	227 ^{bc}	191 ^e	5.75 ^{bc}	8.09 ^b
	Mariana 2624	70.20 ^a	65.20 ^a	39.40 ^a	37.80 ^{ab}	217 ^c	235 ^d	8.49 ^{ab}	9.04 ^{ab}
	Seedling	54.80 ^d	65.54 ^a	37.20 ^{ab}	40.00 ^a	223 ^{bc}	290 ^a	5.53 ^c	10.22 ^{ab}
Simka	GF 677	56.20 ^c	59.53 ^c	37.70 ^a	37.10 ^b	241 ^{c-e}	285 ^a	7.36 ^b	7.44 ^c
	GN 15	60.62 ^{bc}	75.02 ^a	37.80 ^a	36.80 ^b	273 ^b	228 ^{cd}	8.50 ^a	7.73 ^{bc}
	Tetra	59.90 ^{bc}	66.47 ^b	38.20 ^a	37.80 ^{ab}	267 ^{bc}	250 ^{bc}	8.80 ^a	7.11 ^c
	Penta	65.36 ^a	56.54 ^c	37.90 ^a	37.00 ^b	349 ^a	242 ^{b-d}	7.40 ^b	9.29 ^a
	St. Julien	64.40 ^{ab}	67.69 ^b	37.90 ^a	38.20 ^{ab}	221 ^e	261 ^{ab}	5.30 ^d	8.39 ^b
	Myrobalan 29C	61.40 ^{ab}	48.93 ^d	38.30 ^a	38.10 ^{ab}	254 ^{b-d}	281 ^a	6.20 ^c	4.40 ^d
	Mariana 2624	46.30 ^d	49.02 ^d	38.00 ^a	40.20 ^a	227 ^d	216 ^d	7.20 ^b	9.78 ^a
	Seedling	61.60 ^{ab}	40.61 ^e	38.00 ^a	37.80 ^a	238 ^e	237 ^{b-d}	8.43 ^a	7.37 ^c
NO 16	GF 677	54.24 ^b	56.40 ^a	38.40 ^a	37.40 ^a	241 ^{de}	291 ^a	10.35 ^a	6.14 ^b
	GN 15	47.29 ^{cd}	54.64 ^{ab}	39.30 ^a	37.90 ^a	252 ^b	270 ^{ab}	5.98 ^d	8.30 ^a
	Tetra	45.67 ^d	51.95 ^{ab}	38.70 ^a	38.20 ^a	210 ^d	217 ^c	8.16 ^{bc}	8.30 ^a
	Penta	52.21 ^{bc}	51.53 ^{ab}	39.00 ^a	38.32 ^a	243 ^{bc}	241 ^{bc}	8.15 ^{bc}	6.75 ^{ab}
	St. Julien	46.29 ^{cd}	49.35 ^b	38.70 ^a	38.06 ^a	234 ^c	214 ^c	7.22 ^{b-d}	8.55 ^a
	Myrobalan 29C	47.16 ^{cd}	50.16 ^{ab}	38.70 ^a	38.20 ^a	205 ^d	214 ^c	9.24 ^{ab}	7.46 ^{ab}
	Mariana 2624	78.04 ^a	56.85 ^a	39.70 ^a	39.16 ^a	203 ^d	228 ^c	6.95 ^{cd}	8.70 ^a
	Seedling	47.58 ^{cd}	50.97 ^{ab}	38.20 ^a	37.80 ^a	270 ^a	236 ^c	8.13 ^{bc}	7.34 ^{ab}
Cultivar	Rootstock	Photosynthesis (mM CO ₂ /m ² /s)		Ion leakage (%)		Water use efficiency (kg/m ³)		Stomatal conductance (mM/m ² /s)	
		Stress	Control	Stress	Control	Stress	Control	Stress	Control
Zuchelo	GF 677	18.22 ^{ab}	13.13 ^d	33.77 ^c	51.66 ^{ab}	2.02 ^{ab}	1.39 ^{bc}	0.38 ^a	0.06 ^c
	GN 15	17.35 ^b	13.63 ^d	50.30 ^{ab}	47.63 ^b	1.99 ^{ab}	1.45 ^{bc}	0.36 ^{ab}	0.96 ^a
	Tetra	18.52 ^{ab}	16.29 ^{bc}	38.38 ^c	40.17 ^{bc}	2.14 ^{ab}	2.55 ^a	0.31 ^{c-e}	0.26 ^d
	Penta	17.21 ^b	15.12 ^c	38.62 ^c	39.36 ^c	2.16 ^{ab}	2.00 ^{ab}	0.27 ^e	0.39 ^b
	St. Julien	16.21 ^{bc}	17.88 ^b	46.35 ^b	52.54 ^{ab}	2.08 ^{ab}	2.08 ^{ab}	0.32 ^{b-d}	0.26 ^d
	Myrobalan 29C	12.66 ^d	15.46 ^c	37.73 ^c	46.47 ^b	1.63 ^b	1.94 ^{ab}	0.33 ^{bc}	0.40 ^b
	Mariana 2624	16.55 ^{bc}	18.47 ^{ab}	45.77 ^b	45.87 ^b	1.71 ^b	2.25 ^{ab}	0.28 ^{de}	0.34 ^c

Contd.

Table 3 (Concluded)

Cultivar	Rootstock	Photosynthesis (mM CO ₂ /m ² /s)		Ion leakage (%)		Water use efficiency (kg/m ³)		Stomatal conductance (mM/m ² /s)	
		Stress	Control	Stress	Control	Stress	Control	Stress	Control
Greengage	Seedling	15.39 ^c	15.83 ^c	48.47 ^b	41.80 ^b	2.01 ^{ab}	2.08 ^{ab}	0.39 ^a	0.383 ^b
	GF 677	4.33 ^f	18.32 ^{ab}	47.74 ^b	59.87 ^a	1.09 ^{bc}	2.08 ^{ab}	0.28 ^a	0.22 ^c
	GN 15	20.96 ^a	18.02 ^{ab}	36.62 ^c	59.86 ^a	2.30 ^a	1.98 ^{ab}	0.18 ^{bc}	0.17 ^d
	Tetra	9.21 ^e	16.38 ^{bc}	40.55 ^{bc}	21.73 ^{de}	1.27 ^{bc}	1.53 ^b	0.19 ^b	0.30 ^a
	Penta	11.35 ^{de}	17.38 ^b	37.26 ^c	32.68 ^{cd}	1.53 ^b	1.90 ^{ab}	0.18 ^{bc}	0.30 ^a
	St. Julien	11.47 ^{de}	14.16 ^{cd}	37.07 ^c	33.60 ^{cd}	1.59 ^b	1.87 ^b	0.17 ^c	0.28 ^{ab}
	Myrobalan 29C	11.34 ^{de}	19.21 ^a	35.67 ^c	44.27 ^{bc}	1.62 ^b	2.15 ^{bc}	0.15 ^d	0.26 ^b
	Mariana 2624	8.48 ^e	20.39 ^a	35.81 ^c	30.79 ^{cd}	1.36 ^{bc}	2.12 ^{ab}	0.28 ^a	0.28 ^{ab}
Simka	Seedling	17.41 ^b	15.49 ^c	41.17 ^{bc}	24.31 ^{de}	2.01 ^{ab}	1.51 ^b	0.15 ^d	0.26 ^b
	GF 677	15.12 ^c	15.62 ^c	49.74 ^b	45.49 ^b	2.02 ^{ab}	2.19 ^{ab}	0.25 ^a	0.24 ^{de}
	GN 15	14.21 ^{cd}	15.22 ^c	23.50 ^{de}	42.84 ^b	1.85 ^b	2.05 ^{ab}	0.22 ^b	0.27 ^{bc}
	Tetra	12.11 ^d	11.16 ^e	37.26 ^c	38.54 ^c	1.36 ^{bc}	1.81 ^b	0.24 ^{ab}	0.23 ^e
	Penta	2.45 ^g	17.19 ^b	44.10 ^{bc}	47.12 ^b	0.64 ^c	1.91 ^{ab}	0.16 ^{de}	0.31 ^a
	St. Julien	8.39 ^e	13.31 ^d	37.84 ^c	48.06 ^b	1.80 ^b	1.59 ^b	0.14 ^e	0.28 ^{a-c}
	Myrobalan 29C	5.68 ^f	4.46 ^{fg}	25.27 ^d	54.02 ^{ab}	1.95 ^{ab}	0.73 ^c	0.17 ^{cd}	0.13 ^f
	Mariana 2624	12.42 ^d	16.12 ^{bc}	39.33 ^c	44.51 ^{bc}	1.84 ^b	1.60 ^b	0.19 ^c	0.29 ^{ab}
NO 16	Seedling	14.58 ^{cd}	12.28 ^d	44.17 ^{bc}	36.89 ^c	1.85 ^b	1.87 ^b	0.25 ^a	0.26 ^{cd}
	GF 677	7.31 ^{ef}	5.66 ^f	41.29 ^{bc}	24.22 ^{de}	1.25 ^{bc}	0.95 ^c	0.34 ^a	0.17 ^c
	GN 15	14.53 ^{cd}	8.36 ^e	25.65 ^d	20.82 ^{de}	1.35 ^{bc}	1.03 ^{bc}	0.23 ^d	0.25 ^a
	Tetra	10.76 ^{de}	10.21 ^{de}	28.98 ^d	25.06 ^d	1.42 ^{bc}	1.23 ^{bc}	0.22 ^d	0.21 ^b
	Penta	10.68 ^{de}	11.73 ^{de}	30.75 ^{cd}	20.66 ^{de}	1.28 ^{bc}	1.66 ^b	0.29 ^c	0.17 ^c
	St. Julien	13.86 ^d	14.39 ^{cd}	25.79 ^d	19.79 ^e	1.44 ^{bc}	1.53 ^b	0.20 ^d	0.26 ^a
	Myrobalan 29C	10.22 ^{de}	11.12 ^{de}	31.54 ^{cd}	22.51 ^{de}	1.53 ^b	1.71 ^b	0.23 ^d	0.18 ^{bc}
	Mariana 2624	17.11 ^b	15.22 ^c	31.09 ^{cd}	21.41 ^{de}	1.04 ^{bc}	1.65 ^b	0.41 ^a	0.25 ^a
	Seedling	14.59 ^{cd}	12.28 ^d	52.47 ^{ab}	36.63 ^c	1.60 ^b	1.87 ^b	0.15 ^e	0.26 ^a

Means with similar letters in each column are not significantly different at 5% probably level (Duncan's Multiple Range Test).

photosynthetic parameters. Drought stress decreased the physiological traits and photosynthetic efficiency of *Withania coagulans* Dunal (Ghahremani *et al.* 2021). This impact was increased in line with increasing the stress rate. Abiotic stresses such as water deficiency cause the inhibition or severe reduction of photosynthetic electron transfer through damage to photosynthetic apparatus.

Among the cultivars, the highest and lowest transpiration (8.99 and 7 mM H₂O/m²/s) were measured in Greengage, respectively in control and stress conditions (Table 1). On the other hand, among the rootstocks, the highest and lowest transpiration (8.85 and 6.81 mM H₂O/m²/s) were measured in GF 677 (under stress condition) and GN 15 (under control condition), respectively (Table 2). Evaluation of the interaction effect of rootstock and variety on transpiration rate showed that the maximum values (10.70 and 10.35 mM H₂O/m²/s) were measured in Tetra + Greengage + control and GF 677 + NO 16 + stress, respectively. Minimum value

(4.40 mM H₂O/m²/s) was measured in Myrobalan 29C + Simka + control (Table 3).

Cultivars Greengage (under control condition) and Simka (under stress condition) had the highest (17.42 mM CO₂/m²/s) and lowest (10.62 mM CO₂/m²/s) photosynthesis, respectively (Table 1). In the comparison between the rootstocks, Mariana 2624 (under control condition) had the highest photosynthesis (17.55 mM CO₂/m²/s) (Table 2). The lowest photosynthesis (9.77 and 10.42 mM CO₂/m²/s) among rootstocks was obtained in Myrobalan 29C and Penta, both under stress condition. Obtained results related to the triple interaction effect on photosynthesis showed that the highest value (20.96 and 20.39 mM CO₂/m²/s) was obtained in Greengage + GN 15 + stress, and Greengage + Mariana 2624 + control, respectively (Table 3). The interaction effect of Simka and Penta under drought-stress condition had the lowest photosynthesis (2.45 mM CO₂/m²/s) (Table 3).

Hajlaoui *et al.* (2022) showed that the Black Star cultivar

of *Prunus salicina* (L.) was the most tolerant to deficit irrigation, in reason that it maintains a good water status and a high photosynthetic activity. Reduction in canopy volume in young trees encountered with drought stress has been reported (Blaya-Ros *et al.* 2021). Optimization of tree canopy architecture improves efficient light use, productivity and fruit quality (Anthony and Minas 2021). Reduction of stomatal exchanges to save leaf water consumption in plants under stress causes an increase in leaf temperature. The leaf temperature also depends on the morphology of the leaves and wax coating diameter.

The data of the simple effect of stress on the cultivars used showed that the cultivar Zuchelo had the highest water use efficiency (1.97 kg/m^3) in both control and stress conditions. Cultivar NO 16 had the lowest water use efficiency (1.36 kg/m^3) under stress conditions (Table 1). The analysis of the data of the simple effect of stress on the used rootstocks showed that Mariana 2624 cultivar in control conditions and Penta cultivar in stress conditions had the highest (1.9 kg/m^3) and lowest (1.25 kg/m^3) water use efficiency, respectively (Table 2). The table of the triple effect of the factors (Table 3) demonstrated that the highest of water use efficiency (2.55 and 2.30 kg/m^3), respectively, was related to the Zuchelo + Tetra + control and Greengage + GN 15 + stress treatments. Also, the lowest water use efficiency (0.64 kg/m^3) during the investigation of the triple effect of factors was related to the Simka + Penta + stress treatment.

Among the evaluated cultivars, the highest and lowest stomatal conductance rates (0.38 and $0.19 \text{ mM/m}^2/\text{s}$) were measured in Zuchelo under control condition and Greengage under stress condition, respectively (Table 1). On the other hand, among the evaluated rootstocks, the highest and lowest stomatal conductance rates (0.41 and $0.17 \text{ mM/m}^2/\text{s}$) were measured in GN 15 and GF 677 (both under control condition), respectively (Table 2). Evaluation of the interaction effect of rootstock and variety on stomatal conductance rates demonstrated that the maximum values (0.41 and $0.40 \text{ mM/m}^2/\text{s}$) were measured in Mariana 2624 + NO 16 + stress and Myrobalan 29C + Zuchelo + control, respectively (Table 3). On the other hand, the minimum value ($0.06 \text{ mM/m}^2/\text{s}$) was measured in GF 677 + Zuchelo + control (Table 3).

The moderate and severe water stress on *Prunus avium* L. trees showed important stomatal regulation and lower vegetative growth. The minimum osmotic potential for mature leaves was lower than in well-irrigated trees (Blaya-Ros *et al.* 2021). Stomatal conductance in *Prunus salicina* L. showed a strong correlation with leaf water potentials (Hajlaoui *et al.* 2022). Some genes and their expression under drought stress have been identified (Wang *et al.* 2023). One of the factors that reduce the growth of plants in water deficiency conditions is the limitation of photosynthesis. Drought stress could modify the morphology of the leaf (e.g. leaf size and thickness) and reduce transpiration, mesophilic conductance and vegetative growth, which, together with stomatal regulation, would lead to a significant decrease

in photosynthesis (Bhusal *et al.* 2021). Our results confirm these findings.

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