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Relationship between photosynthesis and fruit quality of 'Clemenules clementine' mandarin variety budded on various rootstocks

Turgut Yeşiloğlu[1] Berken Çimen[1,*] Bilge Yılmaz[1] Meral İncesu[1]

[1]Çukurova University, Faculty of Agriculture, Department of Horticulture, Adana, Turkey

[*]Corresponding Author: bcimen@cu.edu.tr

Abstract

'Clemenules' (Nules, Clementina de Nules) has been a very popular variety in fresh mandarin markets especially in the Mediterranean region countries. It is commercially grown on sour orange rootstocks in the calcareous soils of Turkey. However, production of 'Clemenules' needs a substituted rootstock in addition to sour orange due to hypersensitive of sour orange to the "Citrus Tristeza Virus". 'Clemenules' mandarin grafted onto ten rootstocks was evaluated in order to determine the influences of rootstocks on fruit yield, quality and photosynthetic variables of the scion as well as their relationship. Rootstocks significantly affected (p<0.05) fruit yield and using Volkameriana significantly increased fruit yield of 'Clemenules' (44.71 kg tree^{-1}). Similarly, sour orange and Volkameriana rootstocks positively affected fruit weight and height (p<0.05). Total acids (%) and ripening index varied within rootstocks and FA-517 resulted the highest total acids in fruits juice samples of 'Clemenules' whereas the lowest ripening index was determined in fruits grafted on Flhorag1. Leaf chlorophyll concentration (Chl) and leaf chlorophyll fluorescence in the light adapted stage (Fv'/Fm') of the scion differed based on rootstocks. In addition to fruit yield and characteristics, rootstocks also significantly affected variables related to photosynthesis. Cleopatra mandarin, sour orange and Volkameriana increased the photosynthetic rate (P_N), while transpiration rate (E), and stomatal conductance (g_S) of the scion were higher on Volkameriana rootstocks. FA-5 maintained the highest water use efficiency (WUE) in comparison to other rootstocks evaluated. The present research has clearly shown that rootstocks were able to influence the quality of fruits and the physiological activity. Regarding fruit yield and photosynthetic performance of 'Clemenules' mandarin variety, Volkameriana and sour orange performed well. However, considering the calcareous soils of the Mediterranean Region, FA-5 citrandarin proved to be potential rootstock for enhanced photosynthetic rate and WUE.

Keywords: Citrus, Fruit quality traits, Chlorophyll concentration, Net photosynthetic rate

Introduction

Mandarins are called 'easy-peelers' because of their sweet flavor and aroma, loose skins, relatively small fruit size among the edible citrus and are easy to peel and separate into segments (Demirkeser et al., 2009). Currently, mandarins remain the most consumed and demanded citrus species due to some important advantages, such as small fruit, thin skins and easy peeling in all over the world. Turkey has exceptionally reasonable environmental conditions and citrus-producing prospective, with 4.769.726 tons of citrus fruit produced in 2017. At present 65 percent of the export of fresh fruits in Turkey is citrus and the export of citrus fruit, particularly for mandarins, has increased considerably in recent years. Mandarins remain as one of the most the most popular citrus fruits in Turkey, accounting for approximately 30% of the total production (FAO, 2020).

The quality of fruit was always a major interest breeders, producers and consumers which can be manipulated by the us-

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ORCID: Turgut Yeşiloğlu 0000-0001-5820-838X Berken Çimen 0000-0002-9376-1823 Bilge Yılmaz 0000-0003-4158-560X Meral İncesu 0000-0001-7892-3794
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age of rootstocks (Castle, 1995). In addition, rootstocks positively affect scion growth, fruit internal/external quality and fruit yield (Castle et al., 2009; Forner-Giner et al., 2003a), along with photosynthesis (González-Mas et al., 2009). Amongst other physiological progressions, photosynthesis (P_N) is one of the elementary factors of plant productivity and the ability to sustain the carbon assimilation rate under environmental stress (Lawlor, 1995).

Sour orange is commonly preferred as a rootstock for many citrus varieties in Turkey. While sour orange offers many excellent horticultural advantages, its susceptibility to Citrus Tristeza Virus (CTV). In many areas, particularly the western Mediterranean basin, CTV has significantly reduced the use of this rootstock. Sour orange is a good rootstock in areas not subjected to CTV. On the other hand, the CTV-induced problems have destroyed or degraded more than 80 million trees grafted into sour orange rootstock. Citrus breeders are seeking new rootstock genotypes until 1900's. Some of the important targets of citrus rootstock breeding are tolerance/resistance to CTV, alkalinity, cold weather, and positive effect on high fruit yield and quality. So far, Carrizo citrange, Troyer citrange, Swingle citrumelo, C-35 citrange, C-32 citrange obtained by hybridization method and all of them using in citrus production areas successfully (Castle, 1995; Castle et al., 2009; Cimen and Yesiloglu, 2016). Furthermore, two new rootstocks published in Spain have been recorded in Forner et al. (2003b). The two interspecific hybrids that are CTV and have been documented as more tolerant to lime-induced iron (Fe) chlorosis than Carrrizo citrange. Gonzalez-Mas et al. (2009) also carried out a field rootstock experiment in the calcareous soil in order to explore the effects of rootstock on the leaf photosynthesis of 'Navelina' navel and recorded the best performances of the trees grafted on FA-5 under calcareous soils.

Although sour orange (*Citrus aurantium* L.) is still a popular rootstock in the Mediterranean region of Turkey, producers have begun to prefer using citranges (Carrizo and C-35 citranges) in most recently established mandarin orchards due to their positive effects on fruit quality. Sour orange and citranges have generally been satisfactory and, thus, there are limited rootstock studies involving mandarin varieties. In Mediterranean basin, producers still try to find a good rootstock not only tolerant to alkalinity, but also tolerant to CTV.

Regarding these matters, the present study was carried out to evaluate fruit quality and photosynthetic performance of 'Clemenules' mandarin variety budded onto ten important rootstocks in citriculture including commonly used sour orange under calcareous soil condition of the Mediterranean region.

Materials and Methods

Plant Material

Nine years old trees of 'Clemenules cementine' (*Citrus clementina* hort. ex Tanaka) mandarin variety grafted on various rootstocks as presented in Table 1 were used as plant material. Samples of fruits have been harvested from trees located on the citrus rootstock experimental orchards of Cukurova University, Faculty of Agriculture, Department of Horticulture (Latitude, 37°1'27.65" N; Longitude, 35°22'29.30" E; Altitude 49 m) at optimum maturity stage in November and randomly selected from trees. The soil pH ranged from 7.6 to 7.9 at a depth of 0-90 cm in the rootstock experiment orchard which represent slightly alkaline soil conditions of the Mediterranean Region of Turkey with a clay-loam character. The trees were irrigated weekly from May to October using drip irrigation.

Table 1. Genotypes evaluated as rootstocks to 'Clemenules' mandarin variety and scientific names

Genotype	Latin name	Resource*
C-35 citrange	*C. sinensis* (L.) Osbeck x *Poncirus trifoliata* (L.) Raf.	TGK1131
Carrizo citrange	*C. sinensis* (L.) Osbeck x *Poncirus trifoliata* (L.) Raf.	TGK0627
FA-5	*C. reshni* x *P. trifoliate* 'Rubidoux'	IVIA
FA-517	*Citrus nobilis* Lour. x *P. trifoliata*	IVIA
FAO-SRA	[*C. sunki* (Hayata) hort.ex Tanaka x *Poncirus trifoliata* (L.) Raf.]	SRA
Flhorag1	*Poncirus trifoliata* L. Raf. + *Citrus deliciosa* Ten.	SRA
Cleopatra mandarin	*Citrus reshni* Tan.	TGK0947
Swingle citrumelo (Citrumelo 4475)	*Citrus paradisi* Macf. var. Duncan x *Poncirus trifoliata* (L.) Raf.	TGK0702
Sour orange	*Citrus aurantium* L.	TGK1065
Volkameriana	*Citrus volkameriana* V. Ten. Pasq	TGK0623

*TGK, Turkish citrus germplasm. SRA, French citrus research center; IVIA, Spain citrus research center.

Fruit Characteristics and Yield

Fruit yield of each tree evaluated as replicate in this study was weighted during the harvesting period. The fruit weight (g), height (mm), diameter (mm), fruit shape index (fruit height/diameter ratio), rind thickness (mm), juice content (%), total soluble solids (%), titratable acidity (%), and ripening index (RI) were determined. Mature fruits of 'Clemenules' variety budded on ten rootstocks randomly selected (25 fruits for each replicate) from five trees. Fruit samples were immediately transferred to citrus physiology laboratory for quality analysis. Fruits were randomly selected and weighed to determine the average fruit size. The fruit was sized at the equatorial diameter and height with a digital caliper (Mitutoyo CD-15CPX). The fruits were halved and the thickness of the rind was measured with a digital caliper. 25 fruits were weighed then juiced with a regular juicer. As a % of the total fruit weight, the juice was expressed. A portable refractometer was used to detect the overall soluble solid (TSS) content. A titration with 0.1 N sodium hydroxide (NaOH) was used to evaluate the overall acidity (TA) of the juice. The relationship between TSS and TA was determined as ripening index (Lado et al., 2014).

Leaf Chlorophyll Concentration and Photosystem II Efficiency

For the estimation of leaf Chl concentrations by SPAD-502 chlorophyll meter, fully expanded young leaves of 'Clemenules' were used (Minolta Inc., Osaka, Japan). Because SPAD reading and chlorophyll levels in citrus leaves are strongly linked, SPAD reading was used to estimate the concentration of Chl leaves (Jifon et al., 2005). Also, PSII maximum efficiency (*Fv'/Fm'*) readings in a light-adapted leaf phase were measured at the same leaves by using a portable fluorimeter (FluorPen FP100, Photon System Instruments Ltd, Drasov, Czech Republic).

Gas Exchange Measurements

A portable photosynthesis system detected the leaf gas exchange parameters of fully developed 4th to 5th leaves from the shooting apex (model LCA-4, ADC Bioscientific Ltd., Hoddesdon, UK) per each rootstock (Cimen et al., 2014). Portable photosynthesis system measured stomatal conductance, g_S (mmol $m^{-2}s^{-1}$); transpiration rate, E (mmol $m^{-2}s^{-1}$); and net photosynthetic rate, P_N [µmol (CO_2) $m^{-2}s^{-1}$] in each single measurement. The instantaneous photosynthetic water use efficiency was predicted as 'WUE = P_N/E' according to Ribeiro et al. (2009). During the gas exchange measurements, leaf temperature varied from 24 and 26°C and the relative humidity was 55%, where PFD was detected as 750-850 µmol m^{-2} s^{-1}.

Statistical Analysis

The experiment was organized as ten rootstocks and five replicates for each rootstocks in a 'Randomized Block Design'. The data were tested by an analysis of variance (ANOVA). The means and calculated standard deviations were stated. Least significant difference (LSD) test was used for mean comparison within rootstocks when the F test was significant at $p < 0.05$. In addition, the 'correlation coefficients' between all measured parameters were calculated. Data subjected to ANOVA by the SAS v9 statistical analyses software and SigmaPlot® v11 (Systat Software, San Jose, CA, USA) was used for data presentation.

Results and Discussion

Fruit yield have been reported as an important factor in citriculture which is directly affected by rootstock as well as many other deciduous fruit trees (Castle, 1995). In the present study we evaluated the influences of various rootstocks on fruit yield and quality traits of 'Clemenules' mandarin variety. Fruit yield significantly ($p < 0.05$) varied among the investigated rootstocks based on one-year results (Fig 1). The highest fruit yield per tree was determined from the trees grafted on Volkameriana, followed by sour orange. On the other hand, similar fruit yield per trees were recorded from 'Clemenules' variety grafted on C-35, Carrizo, FA-5, FA-517, Flhorag1 and Cleopatra mandarin according to LSD test at α= 0.05. Using FAO-SRA and Swingle citrumelo as rootstocks to 'Clemenules' resulted the lowest fruit yield per tree. On the other hand, long-term studies are needed to determine the effect of rootstock on fruit yield and at least 2-3 years of data are required for an exact statement.

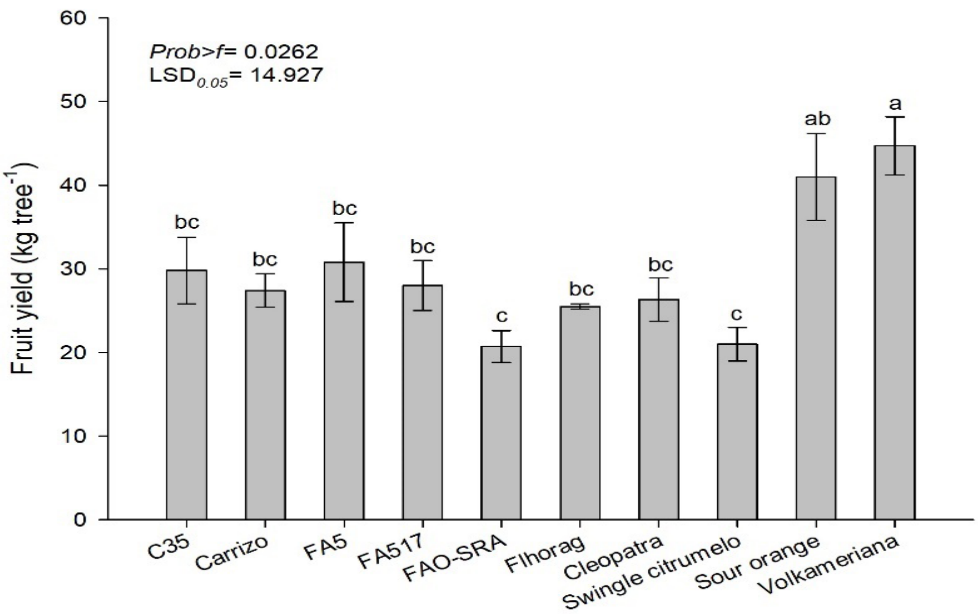

Figure 1. Fruit yield (kg $tree^{-1}$) of 'Clemenules' mandarin variety on various rootstocks

Rootstocks significantly affected variables related to fruit size such as fruit weight ($p < 0.05$) and fruit height ($p < 0.01$) but not significantly affected rind thickness and total soluble solids based on one-year results (Table 2). For producers and consumers, the fruit size is a valuable trait. Medium to large fruits lead to full attention on the fresh market for consumers (Hussain et al., 2013). In our study, except Cleopatra mandarin and Flhorag1, rootstocks produced medium to large fruit size according to recorded fruit weight values. The highest fruit weight was 150.14 g in scion on sour orange followed by Volkameriana (148.60 g) whereas the lowest fruit weight was as 111.48 g from fruit samples on Flhorag1 allotetraploid somatic hybrid. Similar to fruit weight the highest fruit height was determined from fruits on sour orange whereas it was the lowest in for that of Flhorag1. Fruit diameter of 'Clemenules' grafted on various rootstocks varied from 62.88 to 69.11 mm. Although there was no significant rootstock effect on fruit diameter, fruit samples collected from trees on sour orange and Volkameriana had slightly higher fruit diameters in comparison to fruits on other rootstocks. Rootstock had no significant effect on rind thickness which ranged from 3.09 to 4.21 mm.

Table 2. Effects of various rootstocks on fruit weight (g), fruit height (mm), fruit diameter (mm), fruit index and rind thickness (mm) of 'Clemenules' mandarin variety

Rootstock	Fruit weight (g)	Fruit height (mm)	Fruit diameter (mm)	Fruit index	Rind thickness (mm)
C-35 citrange	128.34^{bcd}	59.00^{abc}	65.62	1.11^{c}	3.39
Carrizo citrange	136.11^{abc}	60.05^{ab}	66.36	1.11^{c}	4.21
Cleopatra mandarin	119.00^{cd}	59.70^{abc}	66.26	1.11^{c}	4.04
FA-5	132.01$^{a\text{-}d}$	57.23^{abc}	65.87	1.15^{bc}	3.85
FA-517	124.42^{cd}	56.82$^{a\text{-}d}$	64.97	1.14^{bc}	3.23
FAO-SRA	135.65^{abc}	55.68^{bcd}	66.49	1.20^{a}	3.09
Flhorag1	111.48^{d}	52.37^{d}	62.88	1.20^{a}	3.57
Swingle citrumelo	124.48^{cd}	55.35^{cd}	65.43	1.18^{ab}	3.66
Sour orange	150.14^{a}	60.84^{a}	69.00	1.14^{bc}	3.16
Volkameriana	148.60^{ab}	60.46^{ab}	69.11	1.14^{bc}	3.41
Prob>F	*0.0352*	*0.0187*	*0.1295*	*0.0445*	*0.2296*
$LSD_{0.05}$	*19.773*	*4.284*	-	*0.062*	-

Based on one-year results, rootstocks also did not affect total soluble solids (TSS) of 'Clemenules', however fruit samples collected from those grafted on Volkameriana (11.15%) had slightly lower TSS values than those grafted on other rootstocks under evaluation. In contrast, significant rootstock effect ($p < 0.01$) on total acidity of 'Clemenules' variety was obtained according to a one-way ANOVA (Table 3). Total acid values ranged from 1.14% to 1.32%. The lowest total acids were determined in fruit samples grafted on Cleopatra mandarin and Volkameriana, whereas TA values were higher in fruit samples collected from the rest of the rootstocks. The fruit ripening index is a widely used indicator to determine the citrus fruit maturity level (Lado et al., 2014). Significantly high values of RI were confirmed in fruits of 'Clemenules' grafted on Cleopatra mandarin (16.07), Swingle citrumelo (15.65), and sour orange (15.67), as presented in Table 3. Rootstock had no effect on juice content of 'Clemenules' and fruit juice content ranged from 31.37% to 41.68%.

Fruit internal and external properties are the most important quality parameters and are affected by many factors, such as genetic variability, climate and environment, and rootstock. Several researches revealed that rootstocks significantly affect fruit dimensions and shape (Castle, 1995; Georgiou, 2002; Hussain et al., 2013; Legua et al., 2011). On the contrary, Georgiou (2002) reported that fruit diameter of 'Clementine' mandarin on sour orange, Carrizo citrange and Swingle citrumelo was not significantly affected which is parallel to the results of the present study. In addition, Bassal (2009) reported that the fruits of Marisol mandarin from trees budded on sour orange had higher total acidity (%) than those of Cleopatra mandarin, which is in agreement with the present study.

As a result of the positive linear relationship ($r^2 > 0.8$) between SPAD readings and Chl leaf concentrations reported by Jifon et al (2005), SPAD measurements were used to predict cholorophyll (Chl) levels of leaves in the present study. According to the estimation of Chl concentration by SPAD readings, rootstocks had a significant impact on the leaf Chl content of 'Clemenules' (Table 4). Regarding slightly alkaline soils of the Mediterranean region of Turkey, where the experiment orchard was located at, a remarkable decrease of leaf Chl content in 'Clemenules' grafted on Swingle citrumelo and C-35 citrange. Previously, these rootstocks reported as susceptible to lime-induced iron (Fe) chlorosis by several authors (Castle et al., 2009; Cimen et al., 2014; Pestana et al., 2005). In contrast, the highest leaf Chl content was estimated in the leaves on Volkameriana (58.47), followed by Cleopatra mandarin (58.30). Chl concentrations in the leaves of 'Clemenules' mandarin on Carrizo citrange and FA-5 growing in slightly calcareous soil were not significantly separated and determined in the same sub-group according to the post-hoc test conducted (Table 4). The present study revealed that the Cleopatra mandarin and Volkameriana performed tolerance to slightly alkaline soils likely to sour orange regarding the results obtained for one year. Fe is especially important in the synthesis and stabilization of chlorophyll (Pestana et al., 2011). A number of authors have classified Fe tolerance to citrus rootstocks based on shoot and leaf chlorosis parameters. Sour oranges kept significantly higher Fe concentration in their leaves than trifoliate orange and hybrids (Byrne et al. 1995; Castle et al. 2009).

Similar to leaf Chl concentration, the rootstocks significantly affected PSII efficiency (*Fv'/Fm'*) of 'Clemenules' ($p<0.05$). Cleopatra mandarin and Volkameriana significantly increased PSII efficiency of the scion (Table 4). The declines in chlorophyll fluorescence variables in the case of using trifoliate orange hybrids have been previously reported by Gonzáles-Mas et al. (2009) and Cimen et al (2015). In addition, Pestana et al. (2011) indicated that chlorophyll fluorescence of Newhall navel grafted on Troyer rootstock decreased under iron deficiency. In the present study, PSII activity, in the light adapted period of the leaves, was slightly lower in Swingle citrumelo, in comparison to the rootstocks evaluated.

The precise measurements of leaf gas exchange were conducted with a portable photosynthesis system and the results revealed that the photosynthetic activity of the scion did significantly vary depending on the rootstocks in use. Variables related to photosynthesis of 'Clemenules' mandarin variety grafted on various rootstocks were presented in Table 4. The results of a one-way ANOVA indicated a significant effect ($p < 0.01$) on the net photosynthetic rate (P_N) of 'Clemenules' leaves. P_N of the scion ranged from 1.88 to 5.77 μmol-m^{-2}s^{-1}. 'Clemenules' grafted on Cleopatra mandarin, sour orange and Volkameriana had the highest P_N values with 5.66, 5.44 and 5.77 μmol-m^{-2}s^{-1}, respectively. On the contrary, the lowest P_N was determined in the leaves of 'Clemenules' grafted on Swingle citrumelo (1.88 μmol-m^{-2}s^{-1}). The inhibition of P_N of the leaves on Swingle was found to be corresponding with relatively lower Chl concentration and PSII efficiency (*Fv'/Fm'*) of the leaves on the same rootstock. A one-way ANOVA indicated that rootstock had also significant effect ($p < 0.01$) on leaf transpiration rate (E) of 'Clemenules'. Leaves on sour orange and Volkameriana had the highest E similar to P_N values of these rootstocks. Besides, significant rootstock effect ($p < 0.05$) on leaf stomatal conductance (g_S) was determined. The highest g_S was 101.10 mmol m^{-2}s^{-1} in the leaves of shoots grafted on to Volkameriana rootstock followed by sour orange (92.28 mmol m^{-2}s^{-1}). The lowest g_S was recorded in the leaves of shoots on C-35 citrange (58.33 mmol-m^{-2}s^{-1}). Leaf water use efficiency (WUE) significantly varied between leaves on different rootstocks ($p < 0.01$). The highest WUE was determined on the leaves grafted on FA-5 whereas the lowest WUE values were determined from the leaves on C-35 citrange and sour orange (Table 4). Similar to our findings, FA-5 previously reported to perform better than citranges in terms of photosynthetic activities under high pH conditions (González-Mas et al., 2009)

Physiological parameters like measurements of CO_2-gas exchange can confirm the performance of the plants under high pH conditions (Bavaresco et al., 2006; Chouliaras et al., 2005; Larbi et al., 2006; Molassiotis et al., 2006; Morales et al., 2000; Nenova, 2008). In addition, the lime-induced iron deficiency has been reported to reduce Chl and P_N levels in citrus leaves (Byrne et al., 1995; Hamzé et al., 1986). On the other side, leaf water potential straightforwardly directs leaf transpiration, gas trade, and stomatal conduction in trees developed in alkaline soils (Brodribb and Holbrook, 2003; Eichert et al., 2010; Meinzer, 2002; Sperry, 2000).

Table 3. Effects of various rootstocks on seed number per fruit, total soluble solids (%), total acids (%), TSS/TA, and juice content (%) of 'Clemenules' mandarin variety

Rootstock	Seed number	Total Souble Solids (%)	Total acids (%)	TSS / TA	Juice content (%)
C-35 citrange	10.37^{abc}	12.00	0.90^{ab}	13.44^{ab}	36.48
Carrizo citrange	7.90^{cd}	11.72	0.84^{abc}	14.17^{ab}	39.81
Cleopatra mandarin	13.29^{a}	11.90	0.74^{c}	16.07^{a}	31.37
FA-5	10.15^{abc}	12.20	0.82^{bc}	15.00^{ab}	38.00
FA-517	10.99^{ab}	11.86	0.96^{a}	12.86^{b}	39.07
FAO-SRA	8.59^{bcd}	12.08	0.81^{bc}	15.11^{ab}	36.09
Flhorag1	11.07^{ab}	11.65	0.93^{ab}	12.72^{b}	36.44
Swingle citrumelo	9.26^{bc}	12.18	0.79^{bc}	15.65^{a}	38.91
Sour orange	8.83^{bc}	12.34	0.79^{bc}	15.67^{a}	41.68
Volkameriana	5.28^{d}	11.15	0.70^{c}	16.08^{a}	38.63
Prob>F	*0.0080*	*0.2796*	*0.0245*	*0.0401*	*0.5632*
$LSD_{0.05}$	*2.798*	-	*0.125*	*2.337*	-

Table 4. Leaf chlorophyll concentration and variables related to photosynthesis of 'Clemenules' mandarin variety grafted on various rootstocks

Rootstock	SPAD	PSII (Fv'/Fm')	P_N	E	g_S	WUE
C-35 citrange	51.07±1.42^{ef}	0.634±0.027^{c}	2.51±0.15^{d}	0.57±0.03^{e}	58.33±2.19^{e}	4.40±0.19^{d}
Carrizo citrange	55.33±0.41^{abc}	0.691±0.004^{ab}	4.11±0.12^{c}	0.77±0.02^{c}	75.67±1.20^{d}	5.34±0.19^{ab}
Cleopatra mandarin	58.30±0.89^{ab}	0.710±0.002^{a}	5.66±0.20^{a}	1.05±0.04^{b}	86.32±3.11^{bc}	5.39±0.37^{ab}
FA-5	55.93±1.44^{abc}	0.697±0.007^{ab}	4.77±0.12^{b}	0.83±0.03^{c}	77.17±1.01^{cd}	5.75±0.16^{a}
FA-517	54.97±1.18^{bcd}	0.679±0.036^{abc}	4.04±0.14^{c}	0.71±0.01^{cd}	65.33±5.17^{e}	5.69±0.19^{ab}
FAO-SRA	51.90±0.96^{def}	0.667±0.020^{abc}	2.99±0.13^{d}	0.57±0.02^{e}	62.00±1.73^{e}	5.25±0.16^{ab}
Flhorag1	54.10±1.59^{cde}	0.659±0.003^{bc}	3.03±0.05^{d}	0.59±0.01^{de}	63.67±1.20^{e}	5.14±0.03^{bc}
Swingle citrumelo	49.30±0.36^{f}	0.548±0.023^{d}	1.88±0.13^{e}	0.63±0.05^{de}	63.13±0.47^{e}	2.98±0.28^{e}
Sour orange	56.30±0.57^{ab}	0.687±0.001^{ab}	5.44±0.13^{a}	1.23±0.05^{a}	92.28±4.10^{ab}	4.42±0.16^{d}
Volkameriana	58.47±1.66^{a}	0.716±0.002^{a}	5.77±0.50^{a}	1.26±0.09^{a}	101.10±2.07^{a}	4.58±0.08^{cd}
Prob>F	*0.0002*	*0.0001*	*0.0001*	*0.0054*	*0.0024*	*0.0098*
$LSD_{0.05}$	*3.375*	*0.051*	*0.599*	*0.126*	*9.757*	*0.590*

Table 5. Correlation coefficients analysis between investigated parameters. ** – $p<0.01$, * – $p<0.05$, ns – not significant

Variable	SPAD	PSII	P_N	E	g_S	WUE	Yield	FW	TSS	TA	TSS/TA	Juice (%)
SPAD	1.00	0.75**	0.78**	0.66**	0.68**	0.41*	0.40*	0.15^{ns}	-0.26^{ns}	-0.30^{ns}	0.20^{ns}	-0.14^{ns}
PSII		1.00	0.75**	0.50*	0.49*	0.68**	0.22^{ns}	0.15^{ns}	-0.30^{ns}	-0.24^{ns}	0.13^{ns}	-0.10^{ns}
P_N			1.00	0.88**	0.83**	0.44*	0.47*	0.41*	-0.28^{ns}	-0.40*	0.28^{ns}	-0.09^{ns}
E				1.00	0.89**	-0.02^{ns}	0.60**	0.30^{ns}	-0.32^{ns}	-0.39*	0.27^{ns}	0.01^{ns}
g_S					1.00	0.05^{ns}	0.44*	0.31^{ns}	-0.38^{ns}	-0.40*	0.26^{ns}	-0.06^{ns}
WUE						1.00	-0.10^{ns}	-0.04^{ns}	0.02^{ns}	-0.09^{ns}	0.08^{ns}	-0.21^{ns}
Yield							1.00	0.04^{ns}	0.04^{ns}	0.10^{ns}	0.02^{ns}	-0.11^{ns}
FW								1.00	0.22^{ns}	-0.43*	0.43*	0.28^{ns}
TSS									1.00	-0.23^{ns}	0.49*	-0.13^{ns}
TA										1.00	-0.94**	0.04^{ns}
TSS/TA											1.00	-0.11^{ns}
Juice (%)												1.00
Mean	*54.57*	*0.67*	*4.02*	*0.82*	*74.50*	*4.89*	*30.22*	*131.15*	*11.95*	*0.84*	*14.57*	*37.88*
StD	*3.35*	*0.05*	*1.37*	*0.26*	*14.88*	*0.85*	*13.21*	*18.12*	*0.61*	*0.12*	*2.08*	*5.79*
n	*30*	*30*	*30*	*30*	*30*	*30*	*47*	*46*	*46*	*46*	*46*	*46*

Correlation coefficients revealed significant relationship between variables related to both fruit quality and photosynthesis (Table 5). Higher coefficient between leaf chlorophyll concentration and P_N showed that photosynthesis increased with the increasing amount chlorophyll concentration in the leaves regarding rootstocks. Besides, increasing P_N in the leaves resulted as a significant increase in *E*. Thus, a strong relationship between leaf chlorophyll concentration and photosynthetic variables was observed. Regarding the increase in *E* in the leaves of 'Clemenules' tress increased the fruit yield of the variety, in the present study. In addition to the relationship between these variables, a significant increase was determined in fruit weight according to pairwise correlations. Therefore, regression analyses were performed between these correlations and strong relationships were determined concerning high r^2 values. The regression analysis confirmed that P_N rate was increased by the high Chl content in leaves and similarly high P_N increased fruit weight of 'Clemenules' mandarin variety (Figure 2).

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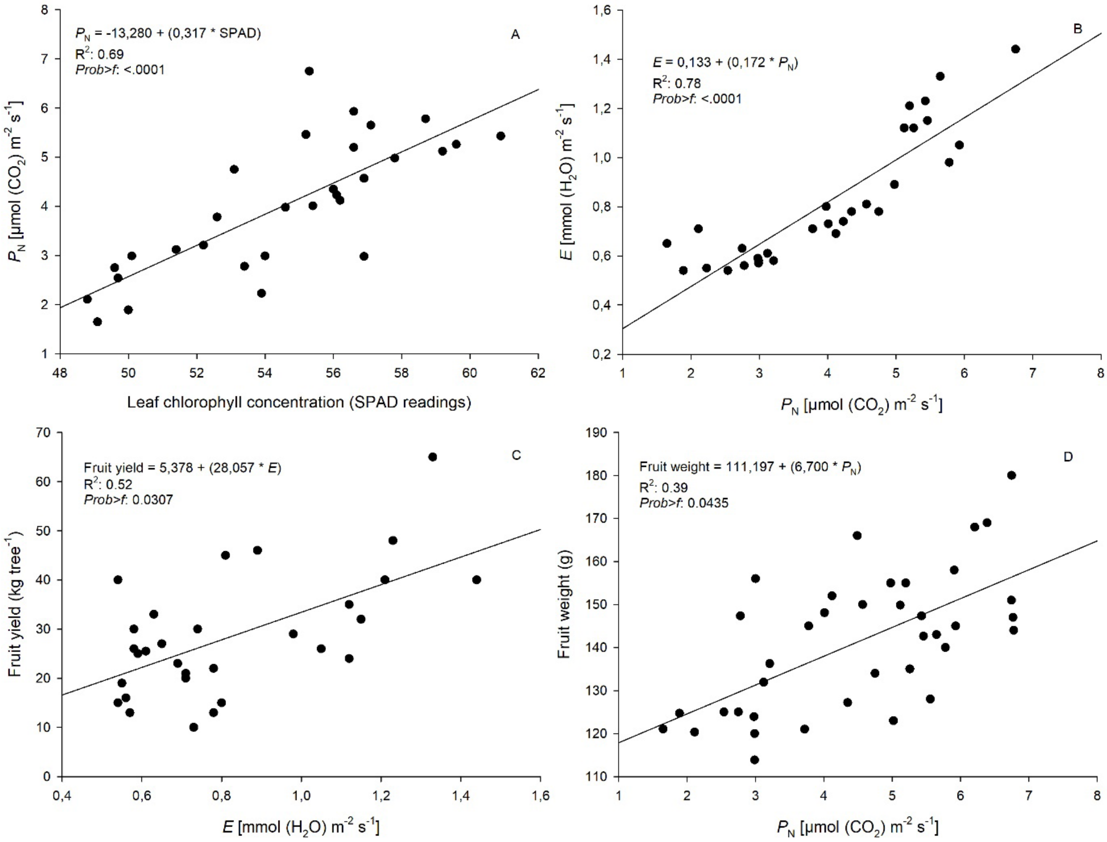

Figure 2. Regressions between A= SPAD readings vs P_N, B= P_N vs E, C= E vs fruit yield, D= P_N vs fruit weight

Conclusion

The present study investigated the effects of rootstock on some fruit quality characteristics and photosynthesis of 'Clemenules' mandarin which is preferred by both Turkey's mandarin growers and consumers. Especially the fruit yield and the fruit weight were remarkably affected by the usage of different rootstocks as well as total acids and ripening index. Sour orange and Volkameriana significantly increased fruit yield due to their high photosynthetic performances. On the other hand, the rootstocks were insignificant on fruit diameter, rind thickness, total soluble solids, and juice content of 'Clemenules'. Since the Mediterranean region of Turkey has calcareous soils, concentration of leaf Chl in 'Clemenules' budded on Swingle citrumelo significantly reduced. Generally, trees budded on Carrizo citrange, FA-5, and FA-517 performed much better than those of C-35 and Swingle citrumelo in terms of positive effects on photosynthetic performance and fruit quality traits. Thus, using these rootstocks for 'Clemenules' should be beneficial especially in terms of their capability to allow high density planting. However, it is worth to mention that long-term studies are needed to determine the exact effects of rootstocks on scion. Therefore, the effects of these rootstock evaluated in the present study will be investigated in terms of fruit yield and quality in the following years.

Compliance with Ethical Standards

Conflict of interest

The authors declare that for this article they have no actual, potential or perceived the conflict of interests.

Author contribution

The contribution of the authors is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

Not applicable.

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Data availability

Not applicable.

Consent for publication

Not applicable.

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