

Influences of girdling and potassium treatments on fruit quality and some physiological characters of ‘Fremont’ mandarin variety

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ABSTRACT

Growing citrus involves cultural treatments such as girdling and foliar potassium treatment to increase fruit size, yield and quality. The aim of the study was to evaluate the effects of single and double stem girdling, potassium nitrate (KNO₃) treatment on leaves and combinations of these treatments on the fruit yield, size and quality characteristics, leaf chlorophyll concentration and leaf nitrogen content, leaf fluorescence (PSII) and leaf sugar content of the ‘Fremont’ mandarin variety. Girdling treatments were applied on the stem by removing 4 mm wide ring of bark at the end of anthesis and after the June fruit drop. Foliar KNO₃ applications were applied at a concentration of 4% twice (90 days and 120 days after full anthesis) in the experiment. The single girdling (SG) and double girdling (DG) treatments on stems increased fruit yield (kg · tree⁻¹) by approximately 40% relative to the control (C). Treatments did not significantly affect the internal fruit quality of the ‘Fremont’ mandarin variety except in fruit colour and appearance. The highest impact on fruit size was found in the DG + KNO₃ treatment. According to treatments and periods, the SPAD values varied between 62.08 and 70.67, whereas the PSII values varied between 0.698 and 0.756. The treatments significantly increased the leaf nitrogen (N) concentration and the fructose, glucose and sucrose concentrations relative to the control. The highest N concentration content was detected in the foliar potassium treatment, and the highest total sugar content was detected in the SG treatment.

Keywords: chlorophyll, citrus, girdling, quality, sugar content

INTRODUCTION

The citrus production of Turkey is 4,301,415 tons in the year 2019. Approximately 39.52% of production is oranges (1,700,000 tons), 33.71% (1,450,000 tons) is mandarins and 22.09% (950,000 tons) is lemons. Turkey exports of 3,785,731 tons of fresh fruit and 19.87% of this fresh-fruit export consists of mandarins (FAO, 2021). Citrus fruits contain unique flavour and minerals, phytochemicals and dietary fibre. For fresh consumption, the visual quality and marketability of fruits can be preserved by long storage (Kahramanoğlu et al., 2020). Among citrus

fruits, mandarins comprise the fruit group that is mainly preferred since they can be easily peeled in fresh consumption. The ‘Fremont’ mandarin variety has high fruit quality, bears fruit early and is suitable for both transportation and storage; however, this variety exhibits periodicity. Its fruits are small, as it has excessive fruit retention; therefore, thinning is necessary. The importance of this fruit in citrus growing has become very high because of its very sweet and flavourful nature, high appeal, suitability for thick planting and early yield.

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Fruit size is one of the most important quality traits, and this characteristic is desired by consumers in both domestic and export markets. The fact that consumers demand large fruits leads to an increase in prices, and fruit size is as important as yield (Guardiola and Garcia-Luis, 2000). One issue that is occasionally encountered in the mandarin industry is the small fruit size, which dramatically reduces the profitability of the product.

There are many factors in citrus-growing that affect the production of quality, such as manual thinning, girdling, chemical and hormone treatments and synthetic auxin treatments and the use of plant growth regulators.

Girdling treatments are applied in citrus production mainly to increase the quality of fruit under various environmental constraints (Freeman and Robbertse, 2003). Girdling can be applied to different organs of trees, such as stems, main branches and smaller branches. Girdling, which increases fruit set and yield, is an agricultural practice that may improve carbohydrate balance and increase carbohydrate availability (Peng and Rabe, 1996). Spring girdling, i.e. pre-bloom removal of a wide strip of bark without injuring the xylem, is widely used in citrus species to increase fruit set and size as well as fruit quality (Mostafa and Saleh, 2006). Girdling treatments increase the fruit retention rate and also reduce the fruit drop before harvest, in addition to increasing parthenocarp, which enables the production of seedless fruits.

Potassium (K) plays an important role and is considered a key element for fruit production and maintenance of fruit quality worldwide. Potassium is most important for external aspects of fruit quality. Low K levels result in small fruits, which are rejected by the fresh fruit and export markets, in spite of their thin rinds and good colour (Erner et al., 2005). Foliar application of nutrients has gained importance in recent years as a tool with which to rectify the deficiencies in nutrients, as sometimes soil application is not effective due to adaphic and environmental hazards. Availability of nutrients through foliar application is easy and quick to the plants. It has been found that foliar application of potassium after flowering increased fruit size and yield of citrus (Vijay et al., 2017).

In this view, we aimed to improve the fruit size and quality of the 'Fremont' mandarin variety by girdling and foliar K treatments as well as their combinations in the present study. Additionally, the effects of various girdling and K treatments on the leaf sugar content, nitrogen (N) content, leaf chlorophyll fluorescence and leaf chlorophyll concentrations of the 'Fremont' mandarin variety were investigated in this study.

MATERIAL AND METHODS

Plant material

The experiments were conducted on 40-year-old 'Fremont' mandarin trees planted on sour orange

rootstock at 7 × 7 m intervals in Dortyol/Hatay, Turkey (latitude 36°50'N; longitude 36°13'E) in 2017. The trees were managed and selected based on uniformity and crop load. The soil in the test site was low calcareous and slightly alkaline, with good organic matter content characteristics. In the experiment site, the average temperature throughout the trial period was determined to be 21–23°C, where the highest average temperature was 34.16°C in July, and the lowest average temperature was 11.38°C in February. The average relative humidity rate was 62.60% (Figure 1).

Girdling and potassium treatments

The control (C): Control trees did not receive any treatments except fertigation and the recommended pest management program for mandarins. **Single girdling (SG):** At the end of anthesis, a girdling knife with a 4-mm diameter was used at 15 cm below the scaffold branch junction level. **Double girdling (DG):** The first girdle was applied at the end of anthesis with a width of 4 mm at 15 cm below the scaffold branch junction level, and the second girdle was applied just after the June fruit drop at 5 cm above the 1st girdle. **Potassium treatment (KNO₃):** KNO₃ was applied at a concentration of 4% twice during the experiment by foliar spray to the entire tree. The first treatment was applied 90 days after full anthesis (30 July 2017), and the second treatment was applied 120 days after full anthesis (30 August 2017). **Single girdling + KNO₃ (SG + KNO₃):** At the end of anthesis (14 May 2017), the 1st girdle with a width of 4 mm was applied, and the 4% KNO₃ treatment was repeated twice. The 1st treatment was applied 90 days after full anthesis (30 July 2017), and the second treatment was applied 120 days after full anthesis (30 August 2017). **Double girdling + KNO₃ (DG + KNO₃):** The first girdle was applied at the end of anthesis (14 May 2017) with a width of 4 mm, and the second girdle was applied just after the June fruit drop (9 July 2017). The 4% KNO₃ treatment was repeated twice. The 1st treatment was applied 90 days after full anthesis (30 July 2017), and the 2nd treatment was applied 120 days after full anthesis (30 August 2017) (Table 1; Figure 2).

The following parameters were examined during the study, to determine the impacts of treatments relative to the control:

For this purpose, branches from four sides (north, south, east and west) of trees subject to every treatment were selected and marked during the full bloom period. Flowers on marked branches were counted and fruit counts were repeated between 7 days and 10 days after petal fall and during the process until ripeness was observed, and then the following characteristics were determined.

The bloom drop ratio (%) was determined according to the formula *Number of dropped blooms/Number of blooms* × 100; the fruit retention rate (%) was determined according to the formula *100 - bloom drop ratio (%)*; the June drop rate (%) was determined according to the

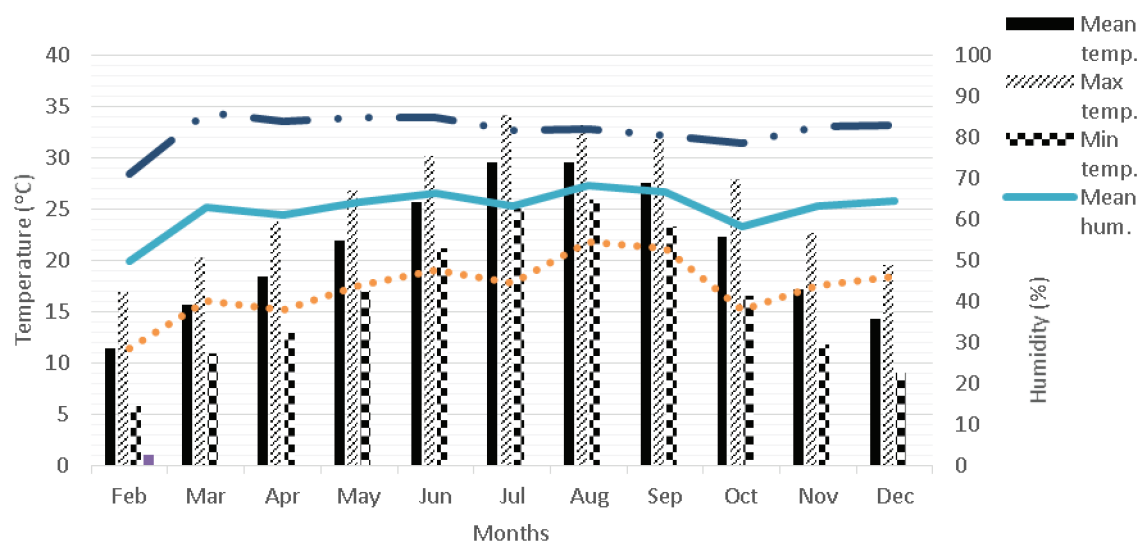


Figure 1. Temperature and humidity values throughout the trial period.

Table 1. Treatments applied during the trial.

Treatment	Treatment Code
Control	C
Single girdling	SG
Double girdling	DG
Potassium treatment (KNO_3)	KNO_3
Single girdling + KNO_3	SG + KNO_3
Double girdling + KNO_3	DG + KNO_3



Figure 2. SG 'Fremont' tree from examined orchard. SG, single girdled.

formula: *Number of fruits after June drop/Number of fruits reaching June drop period* $\times 100$; and the rate of mature fruits (%) was determined according to the formula: *Number of fruits reaching harvest period/Number of blooms* $\times 100$.

Yield and fruit quality

The fruits were harvested in December at the optimum harvest time from each plot. The yield per tree ($\text{kg} \cdot \text{tree}^{-1}$) was obtained by weighing the harvested fruit. A random sample of 50 fruits from each tree was selected and marks are done on the branches to determine the average fruit size. The fruit was measured using a digital caliper (Mitutoyo CD-15CPX) at the equatorial diameter and graded according to the following commercial size classes: >65 mm (Class 1), 58–69 mm (Class 2), 54–64 mm (Class 3), 50–60 mm (Class 4) and <46 mm (Class 5). A random sample of 20 fruits from each tree was collected to analyse fruit quality. The fruit rind thickness and fruit rind colour, fruit juice percentage (%), soluble solids (SSC) (%), acidity (%) and soluble solid/acid ratio were determined. The fruit rind colour was measured at three different points around the equatorial region of each fruit using a Minolta CR 400 reflectance Chroma Meter (Minolta, Osaka, Japan), which provided CIE L^* , a^* and b^* values. Soluble solids were determined with a portable refractometer using a few drops of juice. The total acidity of the juice was determined by titrating 5 mL of the juice sample with 0.1 N sodium hydroxide (NaOH) using phenolphthalein as the indicator (Lado et al., 2014).

Leaf chlorophyll concentration and fluorescence measurements

Leaf chlorophyll concentration and chlorophyll fluorescence measurements were made until harvest time (7 December) at 15-day intervals after the

treatments. In each repetition, measurements were performed on two fully developed leaves ($4^{\text{th}} \pm 5^{\text{th}}$ leaf from the shoot apex) on marked branches of fruitless shoots on four sides of the tree. Leaf chlorophyll concentration was estimated by SPAD readings (Soil Plant Analysis Development-502 Chlorophyll Meter, Minolta Camera Co. Ltd., Japan). The chlorophyll fluorescence parameter ($F_m'/F_v' = \text{quantum yield in light-adapted leaves}$) was measured with a portable fluorimeter (FluorPen FP100, Photon System Instruments Ltd, Drasov, Czech Rep.).

Leaf total N and sugar contents

Twenty-five leaves from each replicate, taken from fruitless shoots in October, were washed and dried for 48 h at 65–70°C, after which they were ground in a plant mill and prepared for analysis. The total N content of leaves were determined according to the Kjeldahl method (Lees, 1971). The sucrose, glucose and fructose contents of leaves were determined with high-performance liquid chromatography (HPLC) according to the method developed by [8]. During the HPLC procedure for chromatographic separation, an HPLC (Shimadzu 10A) reversed-phase C18 column (250 mm $\times$ 4.6 mm $\times$ 5 μm) was used. The mobile phase included acetonitrile: deionised distilled water (80:20, v/v) at a flow rate of 1.3 mL $\cdot$ min $^{-1}$. The injection volume was 20 μL , and sugars were quantified by a refractive index detector (Shimadzu RID-10A, Shimadzu).

The experiment utilised a 'randomized complete block' design with five replicates for each treatment. There was one tree per replication. Data were subjected to one-way analysis of variance (ANOVA) using SAS statistical software (SAS v9.0). The percentages recorded in fruit retention and fruit drop variables were subjected to ANOVA after arc-sin transformation. To compare treatment means, Duncan's multiple range tests was performed to determine if the differences between treatments were significant at a confidence level of $p < 0.05$.

RESULTS AND DISCUSSION

The effects of different treatments on the bloom drop rate in 'Fremont' mandarins grown under the conditions in Dortyol were found to be statistically significant. The highest bloom drop rate was determined in control (C) trees (67.91%). The lowest bloom drop rate was obtained from the SG treatment (55.64%). In terms of the fruit retention rate, the SG treatment (44.36%) yielded the highest value while the C treatment (32.09%) yielded the lowest value (Table 2). The SG treatment had the highest fruit retention, which was dependent on its lowest bloom drop rate. The results obtained by Ibrahim et al. (2016) from the 'Washington Navel' variety, indicating that girdling treatment increased fruit retention, support our findings.

According to the observations performed on the tree following the June fruit drop, the remaining fruit rate was highest in the DG (56.18%) treatment and lowest in the SG + KNO₃ (25.65%), SG (26.53%) and KNO₃ (27.70%) treatments, which were statistically significant in the same group. The results revealed that the June fruit drop was the lowest in the DG treatment (Table 2). Yesiloglu (1999) also reported that the rate of fruits remaining after the June fruit drop as a result of the girdling treatment on 'Clementine' mandarins was highest in the DG treatment.

The fruit yield per tree was highest in the DG (337.50 kg $\cdot$ tree $^{-1}$) and SG (335.00 kg $\cdot$ tree $^{-1}$) treatments, whereas it was the lowest in the C (240.00 kg $\cdot$ tree $^{-1}$) treatment (Table 3). Tuzcu et al. (1992) indicated that DG at the beginning of anthesis on 'Clementine' mandarins increased yield when compared with trees that were not subject to girdling; and Rivas et al. (2006), indicated that girdling in 'Fortune' and 'Satsuma' mandarin varieties could increase the time-dependent impact and yield in varieties with different parthenocarpic abilities. Yesiloglu et al. (2017) analysed the impacts of certain cultural treatments on 'Star Ruby' grapefruit and reported that DG and DG + KNO₃ treatments increased yield relative to the control. Yilmaz et al. (2018) also

Table 2. Effects of KNO₃ and girdling treatments on bloom drop and fruit retention rate of 'Fremont' mandarin (%).

Treatments	Bloom drop rate (%)	Fruit retention rate (%)	Rate of fruits remaining after June fruit drop (%)	Rate of mature fruits (%)
DG	61.88 (50.19) bc	38.12 (39.81) ab	56.18 (51.07) a	6.05 (14.00)
DG + KNO ₃	63.06 (52.65) abc	36.94 (37.35) abc	42.41 (42.19) b	8.14 (15.04)
SG	55.64 (48.25) c	44.36 (41.75) a	26.53 (30.91) c	4.35 (11.78)
SG + KNO ₃	66.93 (56.03) ab	33.07 (35.07) bc	25.65 (30.21) c	4.23 (11.70)
KNO ₃	63.46 (53.65) abc	36.54 (37.16) abc	27.70 (31.44) c	4.79 (11.61)
C	67.91 (57.12) a	32.09 (32.88) c	36.42 (35.42) bc	4.04 (10.95)
Prob > F	0.0296	0.0410	0.0001	0.1348
LSD _{0.05}	5.569	5.265	7.341	NS

Differences between averages were indicated with different letters according to Duncan test.

C, control; DG, double girdle; SG, single girdle; NS, not significant.

Table 3. Effects of KNO₃ and girdling treatments on fruit yield and various pomological characters of ‘Fremont’ mandarin.

Treatments	Yield (kg · tree ⁻¹)	Fruit diameter (mm)	Fruit weight (g)	Rind thickness (mm)	Juice amount (%)	SSC	Acid amount (%)	SSC/Acid
DG	337.50 a	57.28 a	94.20 ab	2.49 c	50.30	10.56	1.19	8.95
DG + KNO ₃	298.00 ab	57.79 a	95.36 a	3.58 a	50.80	10.60	1.16	9.18
SG	335.00 a	55.77 b	85.59 c	2.66 bc	49.09	10.20	1.13	9.05
SG + KNO ₃	276.00 bc	56.60 ab	90.33 b	2.73 bc	49.78	10.48	1.18	9.03
KNO ₃	270.00 bc	57.43 a	91.79 ab	2.91 b	50.24	10.76	1.17	9.26
C	240.00 c	55.31 b	93.75 ab	2.67 bc	45.74	10.92	1.09	10.03
Prob > F	0.0075	0.0047	0.0009	0.0004	0.4374	0.1574	0.4416	0.2943
LSD _{0.05}	51.584	1.352	3.921	0.394	NS	NS	NS	NS

Differences between averages were indicated with different letters according to Duncan test.
C, control; DG, double girdle; SG, single girdle; SSC, soluble solids; NS, not significant.

reported that the DG treatment in ‘Robinson’ mandarins provided a greater yield than in the SG treatment and the control. In this study, we also obtained the highest fruit yield from the DG treatment, and it was determined that the yield increased at a rate of 40% per tree relative to the control, and the findings were similar to the above-mentioned studies.

Fruit size is an important external quality factor in citrus marketing. In general, the fruit diameter classification of this mandarin variety is 3rd grade (54–64 mm) under the ecological conditions with which this study was conducted. The DG + KNO₃ (57.79 mm), KNO₃ (57.43 mm) and DG (57.28 mm) treatments yielded the highest values in terms of this characteristic (Table 3). In addition, Mostafa and Saleh (2006) reported that the girdling treatment increased fruit size; the findings of Yesiloglu et al. (2017), indicating the positive impact of K and 3,5,6-TPA + DG treatments on the fruit size of the ‘Star Ruby’ grapefruit variety relative to the control, supported our study results. The fruit rind was found to be the thinnest in the DG treatment (2.49 mm) and the thickest in the DG + KNO₃ treatment (3.58 mm). The combined effect of the girdling treatment and KNO₃ treatment increased the fruit rind thickness by 34%. Cicala and Catara (1994) reported that there was a positive correlation between the fruit weight, rind thickness and SSC content of KNO₃ treatments in the ‘Tarocco’ orange variety. Similar to our findings, the result obtained by Yilmaz et al. (2018) as a result of using DG treatment in comparison with other treatments (SG, control) in the ‘Robinson’ mandarin variety was fruits with thinner rinds.

Girdling and KNO₃ treatments did not significantly affect juice content (%), SSC (%) and acid (%) content or SSC/acid ratio in the ‘Fremont’ mandarin variety (Table 3). Verreynne et al. (2001) reported that the stem girdling treatment did not impact the internal fruit quality in the ‘Marisol’ variety. Roussos and Tassis (2011) considered the impact of a girdling treatment on the titratable acidity and ripeness index in ‘Nova’

mandarins to be insignificant. Based on previous studies and our findings, it was determined that treatments did not have a significant effect on internal fruit quality characteristics.

During the study, while similarities were found between treatments in terms of L and a* characteristics of fruit rinds, differences in terms of b* and h° values were found to be statistically significant. The b* value was highest in the C treatment and lowest in the KNO₃ and DG + KNO₃ treatments. The h value was highest in C and lowest in KNO₃ (Table 4). Voss (1992) reported that the colour turned from yellow to red as the h° value decreased from 90° to 0°. Accordingly, the fruit rind was found to be close to deep red orange in colour in the KNO₃ and DG + KNO₃ treatments. Mataa et al. (1998) determined that girdling enhanced fruit rind colour during the full bloom period of the ‘Ponkan’ mandarin.

Chlorophyll fluorescence efficiency yielded a value between 0.6980 and 0.7560 in the various treatments done (Figure 3). Rivas et al. (2007) indicated that girdling did

Table 4. The effects of different treatments on fruit rind colour on ‘Fremont’ mandarin.

Treatments	Fruit rind colour			
	L*	a*	b*	h°
DG	57.15	39.75	51.60 cd	52.63 bcd
DG + KNO ₃	56.96	39.82	51.38 d	52.19 cd
SG	57.69	39.21	53.96 ab	53.48 abc
SG + KNO ₃	57.52	39.42	53.33 bc	53.93 ab
KNO ₃	56.07	41.15	51.08 d	51.10 d
C	56.71	39.52	55.44 a	54.57 a
Prob > F	0.1259	0.0767	0.0001	0.0025
LSD _{0.05}	NS	NS	1.719	1.632

Differences between averages were indicated with different letters according to Duncan test.

C, control; DG, double girdle; SG, single girdle.

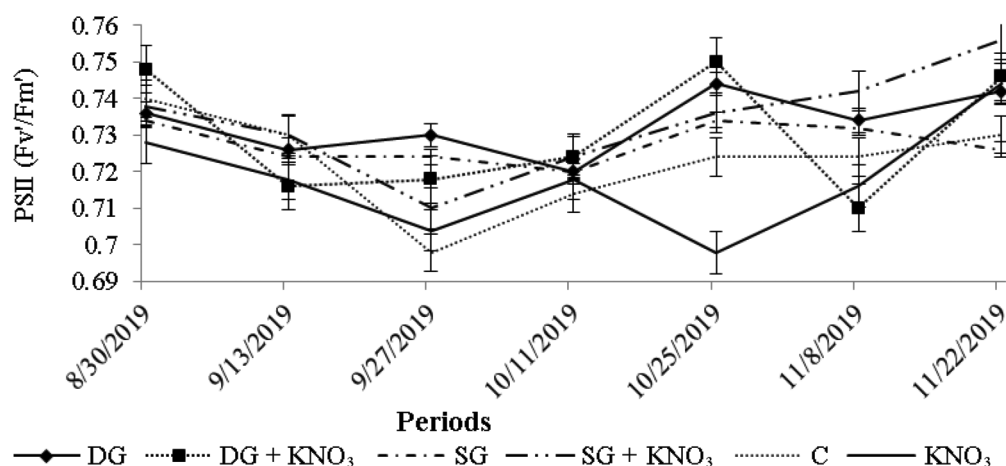


Figure 3. Effects of KNO₃ treatment and girdling on photosynthetic quantum yield (Fv'/Fm') of 'Fremont' mandarin. C, Control; DG, double girdle; SG, single girdling.

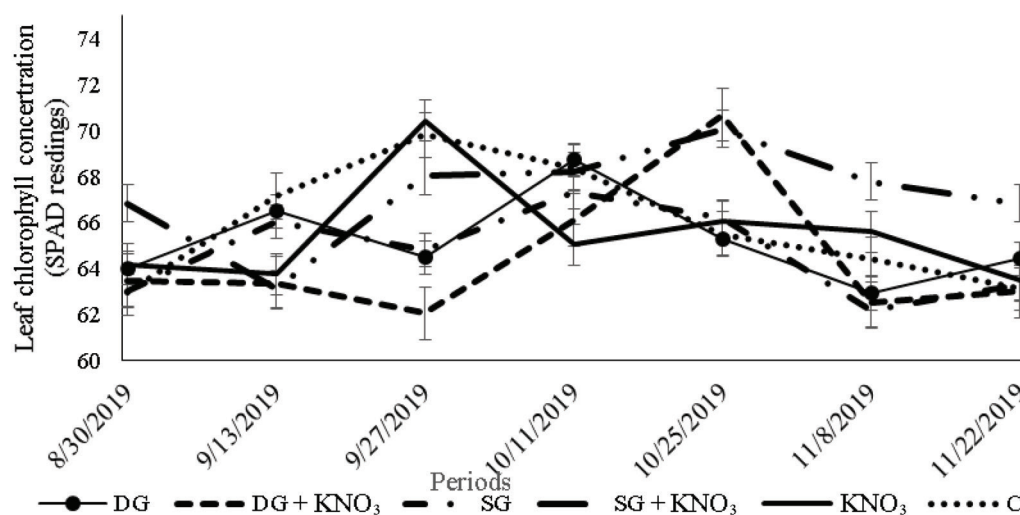


Figure 4. Effects of KNO₃ and girdling treatments on leaf chlorophyll concentration (by SPAD readings) of 'Fremont' mandarin. C, Control; DG, double girdle; SG, single girdling.

not have a significant impact on the PSII efficiency on mature leaves. Yilmaz et al. (2018) reported that a DG treatment on 'Robinson' mandarins displayed a tendency to reduce the PSII efficiency relative to the control. Further, such DG treatments resulted in a variation in the leaf chlorophyll content, and this variation was in the range of 62.08–70.67 (Figure 4). Yilmaz et al. (2018) reported that the impact of different treatments (SG and DG) varied the chlorophyll content between 52.13 and 68.84 in 22-year-old 'Robinson' mandarins. It is believed that the partially high SPAD values in our study could have been caused by the variety, ecology and leaves on which measurements were performed.

The leaf N content of the 'Fremont' mandarin variety significantly differed depending on the treatment. The N level was highest in the KNO₃ treatment (2.73%) and lowest in the C treatment (2.30%) (Table 5). Rivas et al. (2006) also determined that the distribution of mineral nutrients and growth regulators in the plant could vary

after the performing girdling on trees. This study also found that October N values in 'Fremont' mandarins were higher in the treatments than in the control. Mostafa and Saleh (2006) reported that blooming and fruit retention increased in the section of plants that are above the girdling location, depending on the increases in the leaf N content and the C/N ratio.

Modern fruit growers attempt to manipulate the source–sink relationship to guarantee adequate fruit production and quality. The relationship between photosynthetic and non-photosynthetic tissues is less pronounced in fruit trees. Leaves are the most important organ for photosynthesis and leaves accumulate CH at a high rate. Simple sugars, such as glucose, are the principal products of photosynthesis. Soluble CH in fruit trees is composed of monosaccharides (normally glucose and fructose) and oligosaccharides (mainly sucrose). Different environmental factors influence the source–sink relationship (Fischer et al., 2012). Cultural

Table 5. The effect of different treatments on leaf nitrogen, glucose, fructose, sucrose and total sugar contents of ‘Fremont’ mandarin.

Treatments	Nitrogen content (%)	Glucose content (%)	Fructose content (%)	Sucrose content (%)	Total sugar content (%)
DG	2.47 bc	0.08 d	0.08 a	1.82 b	1.973 bc
DG + KNO ₃	2.48 bc	0.32 a	0.05 b	2.16 a	2.350 ab
SG	2.47 bc	0.06 de	0.04 b	2.36 a	2.710 a
SG + KNO ₃	2.60 ab	0.27 b	0.04 b	1.57 b	1.730 c
KNO ₃	2.73 a	0.05 e	0.04 b	2.15 a	2.220 abc
C	2.30 c	0.20 c	0.04 b	2.22 a	2.240 abc
Prob > F	0.0154	0.0001	0.0026	0.0005	0.005
LSD _{0.05}	0.218	0.023	0.015	0.283	0.548

Differences between averages were indicated with different letters according to Duncan test.

C, control; DG, double girdle; SG, single girdling.

treatments such as girdling may increase existing carbohydrate distribution, fruit retention rate and fruit yield (Goren et al., 2003; Rivas et al., 2004). In this regard, upon analysis of the leaf sugar contents in the study, significant differences were observed between treatments. However, the leaf sugar contents were impacted differently by the treatments. In this sense, it was seen that (1) the DG treatment increased the fructose content; (2) the DG + KNO₃ treatment increased the glucose content; and (3) the SG treatment increased the total sugar content significantly compared with other treatments (Table 5). Rivas et al. (2007) determined in their study that, in certain cases, girdling treatment statistically impacted leaf sugar contents at different branches and ages in the ‘Loretina’ mandarin variety relative to the control. This study also found that the DG treatment had a higher impact on fructose content than the other treatments. The varying impacts due to different treatments on the accumulation of other sugars in leaves could have been caused by the differences in the synthesis of sugars in the plant, their transformation into each other, fruit load of tree, vegetative development and climate conditions.

CONCLUSIONS

This study analysed the impacts of girdling and potassium applications on blooming and retention rate, fruit yield and quality, leaf sugar and N content. It was determined that the treatments performed under the scope of the study reduced the bloom drop ratio and increased the fruit retention rate relative to the control, and the girdling treatment yielded the highest value in this regard. It was also determined that the amount of fruit remained in a tree after the June fruit drops was the highest in the DG treatment. Single or DG treatments increased the fruit yield per tree by almost 40% relative to the control. It was determined that the highest values were yielded by the DG + KNO₃ treatment in terms of fruit weight and treatments involving separate and

combined performances of this procedure in terms of fruit diameter. The impact of the SG treatment on yield was not reflected in fruit size relative to that in the C. In this sense, studies on fruit thinning may be required. In terms of fruit juice and quality, the treatments yielded similar results as the control. The impact of treatments on leaf N content was found to be statistically significant. The highest nitrogen content was found in the foliar KNO₃ treatment. The performed applications did not have any negative impact on the photosynthetic capacity of plants; therefore, these variables were included in the study. It was concluded that the SG treatment increased the total sugar content in leaves.

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AUTHOR CONTRIBUTIONS

Both authors contributed equally to the research and manuscript-writing.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

- CICALA, A., AND CATARA, V. (1994). Potassium fertilization effects on yield, fruit quality and mineral composition of leaves of ‘Tarocco’ orange trees. *Proceedings of the International Society of Citiculture*, 2, 618–620.
- ERNER, Y., ARTZI, B., TAGARI, E., AND HAMOU, M. (2005). Potassium affects citrus tree performance.

- The Volcani Center, Institute of Horticulture, Department of Fruit Trees.* 405–414 p.
- FAO (2021). Retrieved from <http://www.fao.org/faostat/en/#data/QC>.
- FISCHER, G., ALMANZA-MERCHÁN, P. J., AND RAMÍREZ, F. (2012). Source-sink relationships in fruit species: A review. *Revista Colombiana de Ciencias Hortícolas*, 6(2), 238–253.
- FREEMAN, T., AND ROBERTSE, P. J. (2003). Internal quality of “Valencia” orange fruit as influenced by tree fruit position and winter girdling. *South African Journal of Plant and Soil*, 20(4), 199–202.
- GOREN, R., HUBERMAN, M., AND GOLDSCHMIDT, E. E. (2003). Girdling: Physiological and horticultural aspects. *Horticultural Reviews*, 30, 1–36.
- GUARDIOLA, J. L., AND GARCÍA-LUIS, A. (2000). Increasing fruit size in citrus thinning and stimulation of fruit growth. *Plant Growth Regulation*, 31(1), 121–132.
- IBRAHIM, M. M., MOHAMED, A. O., MOHAMED, A. H., AND OMAR, A. A. (2016). Effect of some girdling treatments on fruiting behavior and physio-chemical properties of ‘Washington Navel’ orange trees. *Journal of Agriculture and Veterinary Science*, 9(6), 58–65.
- KAHRAMANOĞLU, İ., USANMAZ, S., ALAS, T., OKATAN, V., AND WAN, C. (2020). Combined effect of hot water dipping and *Cistus creticus* L. leaf extracts on the storage quality of fresh Valencia oranges. *Folia Horticulturae*, 32(2), 337–350.
- LADO, J., RODRIGO, M. J., AND ZACARÍAS, L. (2014). Maturity indicators and citrus fruit quality. *Stewart Postharvest Review*, 2(2), 1–6.
- LEES, R. (1971). *Laboratory handbook of methods of food analysis*. London, UK: Leonard Hill Books.
- MATAA, M., TOMINAGA, S., AND KOZAKI, I. (1998). The effect of time of girdling on carbohydrate contents and fruiting in ‘Ponkan’ mandarin (*Citrus reticulata* Blanco). *Scientia Horticulturae*, 73(4), 203–211.
- MOSTAFA, E. A. M., AND SALEH, M. M. S. (2006). Response of ‘Balady’ mandarin trees to girdling and potassium sprays under sandy soil conditions. *Research Journal of Agriculture and Biological Sciences*, 2(3), 137–141.
- PENG, Y. H., AND RABE, E. (1996). Effect of summer trunk girdling on fruit quality, maturation, yield, fruit size and tree performance in ‘Mihowase’ satsumas. *Journal of Horticultural Science*, 71(4), 581–589.
- RIVAS, F., ERNER, Y., ALOS, E., JUAN, M., ALMELA, V., AND AGUSTI, M. (2006). Girdling increases carbohydrate availability and fruit-set in citrus cultivars irrespective of parthenocarpic ability. *Journal of Horticultural Science and Biotechnology*, 81(2), 289–295.
- RIVAS, F., FRASCHINI, C., LANFRANCO, M., BORGES, A., ESPINO, M., GRAVINA, A., AND FRANCO, J. (2004). Characterization and improvement of potential productivity of ‘Nova’ mandarin in Uruguay. *Proceeding of the International Society for Citriculture*, 385–391.
- RIVAS, F., GRAVINA, A., AND AGUSTI, M. (2007). Girdling effects on fruit set and quantum yield efficiency of PSII in two citrus cultivars. *Tree Physiology*, 27(4), 527–533.
- ROUSSOS, P. A., AND TASSIS, A. (2011). Effect of girdling, nitrogen, zinc and auxin foliar spray applications on mandarin fruit ‘Nova’ quality characteristics. *Emirates Journal of Food and Agriculture*, 23(5), 431–439.
- TUZCU, O., KAPLANKIRAN, M., AND YEŞİLOĞLU, T. (1992). Effects of girdling applications on fruit yield and fruit size in “Clementine” mandarin. *Proceeding of International Society of Citrus*, 2, 735–739.
- VERREYNNE, J. S., RABE, E., AND THERON, K. I. (2001). The effect of combined deficit irrigation and summer trunk girdling on the internal fruit quality of ‘Marisol Clementines’. *Scientia Horticulturae*, 91(1–2), 25–37.
- VIJAY, V., DALAL, R. P. S., BENIWAL, B. S., AND SAINI, H. (2017). Effect of foliar application of potassium and its spray schedule on yield and yield parameters of sweet orange (*Citrus sinensis* Osbeck) cv. ‘Jaffa’. *Journal of Applied and Natural Science*, 9(2), 786–790.
- VOSS, D. H. (1992). Relating colourimeter measurement of plant colour to the Royal Horticultural Society Colour Chart. *HortScience*, 27(12), 1256–1260.
- YEŞİLOĞLU, T. (1999). Klemantin mandarininde ilkbahar ve yaz bileziklerinin meyvelerin pomolojik özellikleri ile bilezik yarası kapanma oranları üzerine etkileri. *Akdeniz Üniversitesi Ziraat Fakültesi Dergisi*, 12(1), 37–42.
- YEŞİLOĞLU, T., KOÇ S., AND ÇİMEN B. (2017). The usage of auxins with various cultural techniques to increase fruit size in ‘Star Ruby’ grapefruit. *Fresenius Environmental Bulletin*, 26(10), 5717–5722.
- YILMAZ, B., ÇİMEN, B., İNCESU, M., YEŞİLOĞLU, T., AND YILMAZ, M. (2018). Influence of girdling on the seasonal leaf nutrition status and fruit size of ‘Robinson’ mandarin (*Citrus reticulata* Blanco). *Applied Ecology and Environmental Research*, 16(5), 6205–6218.

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