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Foliar application of mineral nutrients after non-traditional flower removal improved the yield and fruit quality of pomegranate trees

*Mohammad J. Karami *[1], Abdohossein A. Jahromi[2] and Somayeh K. Shahrabadi[2]*

Address:

[1] Fars Agricultural and Natural Resources Research and Education Center, AREEO, Shiraz, Iran

[2] Horticultural Department, Agricultural Faculty, Islamic Azad University, Jahroom, Iran

*Corresponding author: ***Mohammad J. Karami*** email: jkarami299@yahoo.com

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ABSTRACT

This study aimed to determine the effect of foliar spraying of certain minerals on the yield and fruit quality of pomegranate trees with fewer flowers than normal. In the trees planned for flower thinning, after 50% of the flowers bloomed, they were removed by hand, assuming these flowers were damaged by biotic or abiotic agents and would eventually fall. The tested trees were subjected to the following treatments: T1- Remove the flowers + foliar spraying of complete micronutrient fertilizer (4 g/L), T2- Remove the flowers + foliar spraying of Zn as $ZnSO_4$ (3 g/L) + K as Soloptas (3 g/L). T3- Remove the flowers + foliar spraying of Zn as $ZnSO_4$ (3 g/L) + Soloptas fertilizer (3 g/L) + N as Urea (2 g/L). T4- The trees were allowed to flower continuously without foliar application of nutrients. T5- Flowers were removed, but foliar spraying was not done (Control). Foliar spraying was repeated four times at interval of 15 days. The results showed that the maximum yield (66.90 kg of fruit/tree) was in T4. However, the effect of foliar spraying on fruit yield/tree, number of fruit/trees, average fruit weight (g), cracked fruit (%), average aril weight was significant in trees with thinned flowers compared to control (T5). The highest and lowest increase in yield per tree due to foliar application of nutrients was in T3 and T1, respectively. Foliar spraying increased the yield in T3, T2, and T1 treatments compared to the control by 68%, 64%, and 53%, respectively.

Keywords: Flower drop; Flower thinning; Foliar spraying; Macronutrients; Micronutrients; Shirin-Shahvar.

INTRODUCTION

Pomegranate (*Punica granatum* L.) is one of the oldest known edible fruits and is native to Iran, grown extensively in arid and semi-arid regions worldwide. Additionally, pomegranate is a major fruit crop in the world's Tropical and Subtropical regions (Meena *et al*., 2018; Sharma *et al*., 2018; Sarkhosh *et al*., 2021).

In Iran, the total cultivated area of pomegranate is 81282 hectares with a total production of 1,201,848 tons and Fars province ranks first in pomegranate production (Ahmadi *et al.,* 2021). Farouqh region is one of the important pomegranate production areas in this province. Shirin-Shahvar with high yield, sweet taste, thin skin, and medium to large fruits, is the main pomegranate cultivar of this region (Al-Aslan *et al.,* 2023). Flowers of pomegranate are generally perfect, containing both male and female parts. Hermaphrodite flowers open earlier than other flowers. Flowering in the northern hemisphere generally occurs between February and April, and in the southern hemisphere between July and August, Depending on cultivar and weather conditions (Kumar *et al*., 2019). Both pin and thrum type blossoms are identified in perfect blossoms (Kumar *et al.,* 2020; Ferrea *et al*., 2023). The first flowering period of pomegranate begins in mid-April and continues until mid-May. These flowers are abundant and mostly herbaceous; with about 25% setting fruit while the rest will senesce and drop. Fruits from the first flowers are large and marketable (Kumar *et al.,* 2020).

Nutrition plays a vital role in the production of any fruit crop, and foliar spraying is one method of plant nutrition. In many crops and fruit trees, foliar spraying is used to mitigate the damages caused by biotic and abiotic stresses (Abdel-Aziz and Geeth, 2018; Azza *et al*., 2018; Sarhan and Abdel-Gayed, 2022; Abdelraouf and Mouard, 2023; El-Mehy *et al*., 2023; Gad *et al*., 2023). Additionally, in pomegranate, both macro and micronutrients improve the quality and quantity of production. Foliar application of different micronutrients at proper stage helps improve fruit yield, quality and physiochemical characteristics of pomegranate (Yadav *et al.*, 2018; Hussaein *et al*., 2024).

Fatahi *et al*., (2020) showed that fruit thinning significantly reduced the number of fruits, but fruit weight and size increased significantly compared to the control. Kahramanoglu *et al*. (2018) studied the physical and chemical properties of pomegranate fruits ('Wonderful') in an experiment with four levels of hand thinning. The results showed that the number of fruits on the tree significantly influences the average fruit weight, number of arils, fruit sizes, and commercial yields. They concluded that leaving more fruit on the tree not only reduced the total yield, but also reduced the average fruit weight for all sizes.

Although the effects of many foliar chemicals, macronutrients and micronutrients on the yield and quality of pomegranate fruit have been studied by many researchers (Chater and Garner, 2018; Dhurve *et al*., 2018; Yadav *et al*., 2018; Pavhane *et al*., 2020; Maity., *et al*., 2021; Morwal and Das, 2021), the effect of mechanical or hand thinning on fruit development and quality attributes in pomegranate has also been examined (Kahramanoglu *et al*., 2018; Fattahi *et al*., 2020). However, in the case of abnormal flower drop due to biotic and abiotic agents, the effects of foliar nutrient spraying on the yield and quality of pomegranate fruit have not been investigated. Therefore, this research may be the first in this field.

This study aimed to examine the effect of foliar spraying with various agro-minerals on the yield and fruit quality of pomegranate trees with fewer flowers than normal after 50% of the flowers bloomed by hand, assuming that biotic or abiotic agents damaged these flowers and would eventually cause them to fall. However, in this research, the stress was not real, but the manual removal of flowers was considered a direct effect of the stress. On the other hand, both biotic and abiotic stresses, in addition to direct effects, can have indirect effects on the blooming of pomegranate tree flowers, eventually causing them to fall. Indirect effects involve weakening the overall health of the tree, which in turn affects flower development and bloom quality. Therefore, this issue should be included in the results of this research. To explain this issue, the strengthening effects of the four stages of foliar nutrition (Experimental treatments) on these trees can be considered a factor in enhancing the trees and reducing the indirect effects of these stresses on their health.

MATERIAL AND METHODS

This study was conducted over two successive years on pomegranate (*Punica granatum* L.) Shirin-Shahvar cv. trees in a pomegranate orchard in Farouqh region of Iran, located at a longitude of 29.57.37 and a latitude of 53.21.51 and 1587m above sea level. The tested trees were as uniform in vigour as possible, 15 years old growing in sandy soil under drip irrigation system. The distance between the trees was 5 x 5 meters, and they were subjected to the same agricultural methods recommended by the Research Institute of Horticultural Sciences.

In the trees planned for flower thinning (T1, T2, T3, and T5), the removal of flowers was manually practiced after 50% of the flowers bloomed, assuming that biotic or abiotic agents would damage and and cause them to eventually fall.

Treatments:

The tested trees were subjected to the following treatments:

T1- Removal of flowers + foliar spraying of complete micronutrient fertilizer (4 g/L).

The complete micronutrients fertilizer was produced by Azar Company for the Soil and Water Research Institute (Iran), with the formula: 5% $FeSO_4$, 4% $MnSO_4$, 2% Citric acid, 5% $ZnSO_4$, 2% $CuSO_4$, and 1% Nitrogen from ammonium sulfate.

T2- Removal of flowers + foliar spraying of Zn as $ZnSO_4$ (3 g/L) + Soloptas fertilizer (3 g/L).

T3- Removal of flowers + foliar spraying of Zn as $ZnSO_4$ (3 g/L) + Soloptas fertilizer (3 g/L) + N as Urea (2 g/L).

T4- The trees were allowed to flower continuously without foliar application of nutrients.

T5- Flowers were removed, but foliar spraying was not done (Control).

Foliar spraying was repeated four times with an interval of 15 days.

Studied traits:

After the fruits had ripened (TSS > 14Brix), they were harvested by hand, and the following parameters were recorded.

Fruit yield (kg)/tree: At the time of harvest, the fruits of each tested tree were picked, and weighed, and the total yield was estimated.

Total number of fruits: The total fruits of the trees in each plot were harvested, counted and recorded as the total number of fruits.

Fruit Weight (g): Yield was divided by the number of fruit in each plot.

To assay the quality of fruits in terms of peel weight and aril percentage, the fruits were manually peeled, and the weight of total arils and peel were measured.

The total soluble solids percentage (TSS %) was determined using a hand refractometer.

Total titratable acidity (TA %), expressed as grams of citric acid per 100 g of juice, was measured by titration against 0.1 N NaOH solution, using 1 ml diluted juice in 10 ml distilled water with phenolphythalein as the indicator. The total acidity percentage was calculated (A.O.A.C., 2006). The TSS/acid ratio was also calculated.

The percentage of cracked fruits was calculated by dividing the number of cracked fruits per tree by the total number of fruits per tree.

Statistical analysis:

The randomized complete block design with three replicates was applied to experiments. Each plot consisted of three trees (5 treatments × 3 replicates × 3 trees = 45 trees). The data from two years of experiment were subjected to the combined analysis of variance and differences among the means were determined for significance following Duncan multiple range test (DMRT) P≤0.05 with the computer program MSTATC.

RESULTS

The maximum fruit yield per tree (66.90 kg of fruit/tree) was observed in T4 (Fig. 1). In T1, T2, and T3 (flowers removed) compared to the control (T5), foliar spraying had a significant effect on fruit yield per tree, number of fruits per tree, average fruit weight (g), cracked fruits (%), and average aril weight (Table 1).

Maximum fruit weight and maximum fruit peel weight were recorded in T3 (trees sprayed with Zn + K + N). Fruit weight in T2 was not significantly different from the control (Table 1).

The number of fruits per tree in T1, T2, and T3 was higher than that in the control. The highest and lowest numbers of fruits per tree were in T2 and T1, respectively.

The minimum percentage of cracked fruit was observes in the control trees and T4 (trees were allowed to flower continuously without foliar application of nutrients), respectively, while the maximum was in T2 (trees sprayed with Zn + K).

Additionally, the results showed that the foliar spray treatments (T1, T2, and T3), improved the average weight of the arils compared to the control. The maximum and minimum aril weights were in T1 and control, respectively. Fruit weight in control trees was lower than in other treatments.

The maximum peel weight was in T3 (trees sprayed with Zn + K + N), and there was no significant difference in other treatments.

Aril weight and aril/peel ratio increased in T1 (trees sprayed with complete micronutrient fertilizer) and T2 (trees sprayed with Zn + N). The highest TSS% was in T2 and the control, respectively. And there was no significant difference in TSS% in other treatments. There was no significant difference among treatments for TA%, pH and TSS/TA.

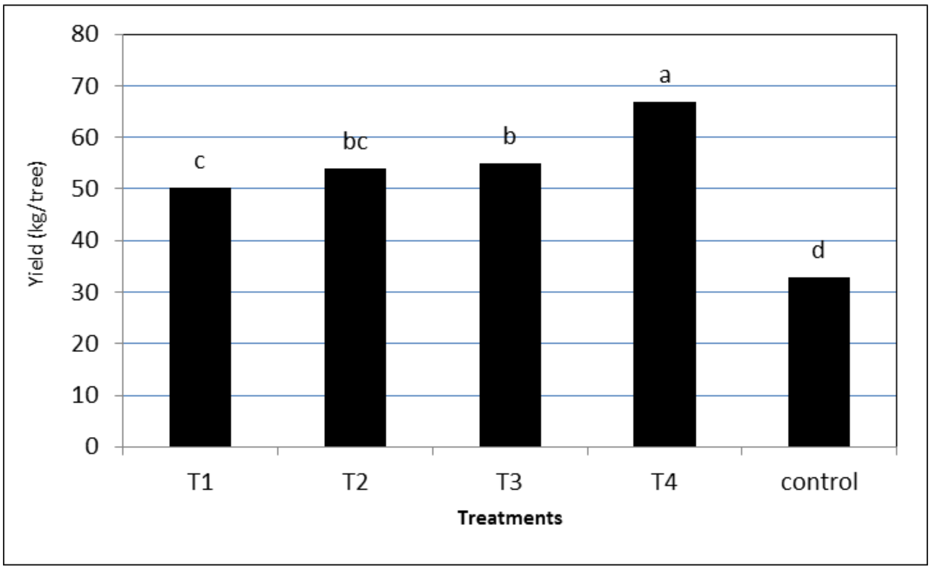

Fig. 1. The effect of foliar spraying treatments on Fruit yield per tree. Different alphabetic letters represent the significant differences among the treatments at $p < 0.05$, according to Duncan's test.

Table 1. Effect of foliar spraying on yield and physicochemical properties of pomegranate during two consecutive years

Treatments	Fruit yield /tree (Kg)	No. of fruits /tree	Fruit average weight (g)	No. Cracked Fruit	Cracked fruit (%)	No. Healthy Fruit	Healthy Fruits (%)	Healthy Fruit Weight	Average aril weight	Peel weight (gr)	The aril/peel ratio	TSS (%)	TA (%)	TSS/TA Ratio	pH
T1	50.27^{c}	213.5^{b}	235.7^{b}	9.0^{b}	4.24^{b}	187.3^{c}	87.5^{ab}	43.1^{b}	167.3^{a}	93.3^{b}	1.79^{a}	15.37^{b}	1.72^{ns}	8.90^{ns}	3.36^{ns}
T2	53.90^{bc}	253.5^{a}	212.5^{c}	16.3^{a}	6.47^{a}	216.7^{b}	85.6^{b}	46.2^{b}	146.1^{abc}	86.0^{b}	1.70^{a}	16.70^{a}	1.81^{ns}	9.72^{ns}	3.73^{ns}
T3	55.00^{b}	197.0^{bc}	279^{a}	8.7^{b}	4.42^{b}	169.0^{c}	85.6^{b}	48.8^{b}	158.1^{ab}	108.0^{a}	1.46^{b}	15.20^{b}	1.73^{ns}	8.81^{ns}	3.8^{ns}
T4	66.90^{a}	278.7^{a}	240.5^{b}	6.3^{b}	2.29^{c}	251.3^{a}	90.1^{ab}	62.2^{a}	$135.^{6bc}$	96.0^{b}	1.50^{b}	15.30^{b}	1.76^{ns}	8.69^{ns}	3.83^{ns}
T5	32.8^{d}	183.0 c	201.3^{c}	1.0^{c}	0.55^{d}	169.3^{c}	92.4^{a}	34.7^{c}	126.1^{c}	86.7^{b}	1.54^{b}	16.10^{ab}	1.76^{ns}	9.26^{ns}	3.85^{ns}

In a column, means followed by a common letter (s) are not significantly different at the 5% level by DMRT

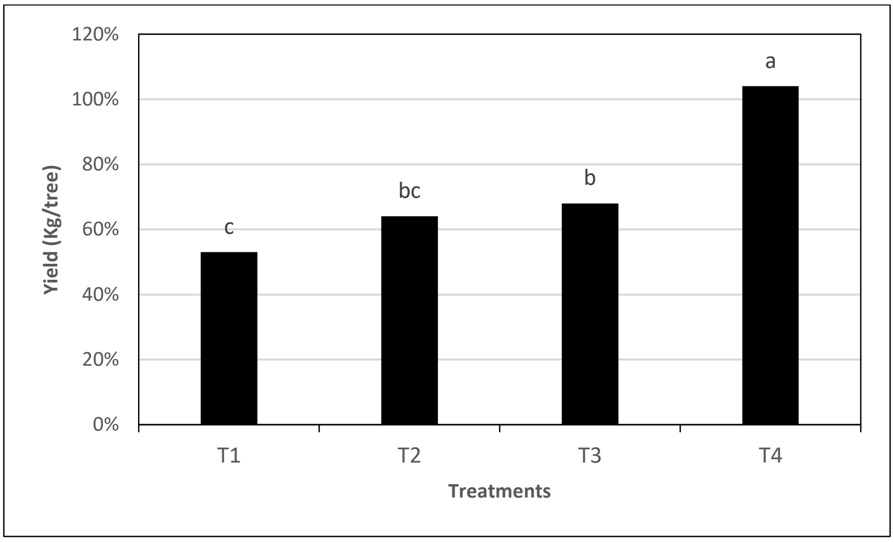

Fig. 2 Percentage increase in yield due to foliar spraying (T1, T2, and T3) compared to control trees. different alphabetic letters represent the significant differences among the treatments at p<0.05, according to Duncan's test

DISCUSSION

The maximum yield of fruit per tree (66.90 kg fruit/tree) was in T4. This result was not unexpected because flowers were not removed in this treatment, and these trees had twice as many flowers as the other trees. However, in trees whose flowers were removed (T1, T2, and T3), foliar spraying increased the yield of fruit per tree compared to control. This increase in yield in T3, T2, and T1 trees compared to the control was about about 68%, 64%, and 53%, respectively (Fig. 2). The effects of foliar spraying of nutrients on the yield and quality of pomegranate have been reported (Chater and Garner, 2018; Dhurve *et al*., 2018; Yadav *et a*l., 2018; Pavhane *et al*., 2020). The significant effects of foliar spraying on fruit yield and quality in T1, T2 and T3 in our research are in agreement with these reports. Additionally, the results of T1, T2, and T3 treatments confirmed the effect of foliar spraying on increasing yield and improving some features of pomegranate after removing its flowers. Several factors are involved in increasing the yield of trees whose flowers have been removed (T1, T2, and T3). One reason could be the presence of Zn in these foliar treatments and its effect on fruit yield (Amer, *et al*., 2020; Maity et al., 2021).

In our experiment, the effects of Zn on the yield and physicochemical properties of pomegranate my explain the improvment in yield and fruit characteristics in foliar-sprayed trees (T1, T2, and T3). The effect of Zn on improving the yield and quality of pomegranate has been reported (Yadav et al., 2018; Maity et al., 2021). Samara and Shalan (2013) showed that fruit thinning reduced the number of fruits but increased fruit weight and size. Additionally, Mohsen and Osman (2015) demonstrated that fruit thinning increased fruit weight. In our study, control trees had fewer fruits than T4, as they had 50% fewer flowers than T4 trees. In foliar-sprayed trees (T1, T2, T3) like the control, 50% of the flowers were removed, but these trees had more fruits than the control. This increase resulted in the number of fruits in T2 trees (50% of flowers removed) being the same as the number of fruits in T4 trees (allowed to flower continuously without foliar application of nutrients). Addiotionally, thinning flowers caused a decrease in fruit weight in control and T2 trees, but did not affect T1 trees, these results were contrary to those of Samara and Shalan (2013) and Mohsen and Osman (2015).

However, in agreement with their findings, fruit weight increased in T3 treatment (trees sprayed with Zn + K + N) by thinning flowers. Foliar spraying contributed to the increase in fruit weight in these trees, and nitrogen may be responsible for this increase. Samara and Shalan (2013) and Mohsen and Osman (2015) conducted fruit thinning, while, we performed flower thinning. Therefor, our differing results indicate that the effects of fruit thinning on the number and weight of fruit can be different from those of flower thinning. Additionally, these results demonstrate that foliar spraying of certain nutrients (Zn, K, and N) can be effectively in increase the number and weight of fruits.

Fruit weight in T2 was not significantly different from the control. This means that foliar application of Zn + K had no effect on the weight of pomegranate fruits. However, when these elements were combined with nitrogen (T3) there was a significant effect on fruit weight, producing the heaviest fruits compared to other treatments. The production of the Maximum number of fruits and the highest yield per tree in T2 and T3 treatments, which contained Zn, indicates that the effect of Zn sprayed in combination with some macronutrients such as K and N on increasing the number of fruits and fruit yield/tree is greater than the effects of using Zn in combinations with other micronutrients (T1). Foliar application of some micronutrients, particularly Zn, Mn, and B has received greater attention in the studies involving the use of inorganic fertilizer application in pomegranate growing (Chater and Garner, 2018; Maity *et al*., 2021). There is also evidence of the effect of Zn foliar application in combination with micronutrients such as B, Mn, Fe on increasing the yield and number of fruits per tree (Dhurve *et al*., 2018; Gawade *et al*., 2018; Yadav *et al*., 2018; Jat *et al*., 2020; Maity *et a*l., 2021). However, there is a little information about the effect of Zn spraying in combinations with N or K in this context.The maximum fruit and fruit peel weight was observed in T3 (trees sprayed with Zn + K + N), It can inferred that the heavier peel of the fruit may be one of the reasons why the fruit from these trees is heavier than those from other treatments. Unlike T3, the increase in yield per tree in T2 was not related to the fruit weight or fruit peel weight. but was due to a higher number of fruits in this treatment.

The lack of significant difference in fruit weight in T2 compared to the control trees means that foliar application of Zn + K had no effect on the fruit weight. However, when these elements were combined with N (T3) there was a significant effect on fruit weight, producing the heaviest fruits. This may be due to the effect of N or its interaction with Zn and K. Interestingly, combining nitrogen with potassium had a significant effect on the weight of pomegranate fruits. These results were consistent with those of Poonam Kashyap *et al*. (2012). They reported that maximum fruit weight was obtained in treatments containing N in combination with K. A grater number of fruits per tree in foliar spraying trees (T1, T2, and T3), compared to control, indicated the effective role of foliar application of nutrients on fruit set in pomegranate trees, although the effects of these treatments on fruit set were not the same. Also, the production of the highest and lowest number of fruits per tree in T2 and T1 showed that the effects of Zn + K foliar application were more effective than the microelements in single-way spraying (T1). On the other hand, the number of fruits in T3, which contained Zn, K, and N, was significantly less than the number of fruits in T2. This means that N had no effect on the number of fruits in these trees.

The observation of the least number of cracked fruits in the control trees shows that the Shirin Shahvar cultivar is resistant to fruit cracking. However, in this experiment, foliar spraying caused a significant increase in fruit cracking percentage (Table, 1). The high percentage of cracked fruits in the no-nitrogen treatment (T2) was unexpected because Pal *et al*. (2017) reported that increased nitrogen leads to fruit cracking, a finding that is inconsistent with the results of our study. In our research, with the addition of nitrogen in T3 (trees sprayed with Zn + K + N) compared to T2, which did not contain nitrogen (trees sprayed with Zn + K), fruit cracking decreased (Table 1). The result of our research which showed higher aril weight in all treatments compared to the control and lower fruit weight in the control compared to other treatments, including T4 (where trees were allowed to flower continuously without foliar application of nutrients) was not consistent with the findings of Sharma and Singh (2002). They reported that thinning pomegranate flowers early in flowering increased fruit weight. This result was not consistent with our research findings. On the other hand, the significant increase in fruit weight from foliar treatments demonstrates the effectiveness of this technique in enhancing the yield and weight of pomegranate fruits.

Nutrition plays a vital role in the production of any fruit crop. Both macronutrients and micronutrients improve the quality and quantity of pomegranates. Foliar application of different micronutrients at the proper stage helps improve fruit yield, quality, and physiochemical attributes of pomegranate. It also helps in correcting micronutrient deficiency and improves quality and physiochemical attributes (Yadav *et al.,* 2018). Also, in our study, foliar application of macro and micronutrient treatments increased yield and improved some fruit attributes compared to the control. Finally, to compensate for the decrease in yield caused by the damaged flowers of pomegranate trees, spraying the nutrients used in this experiment, preferably Zn (3 g/l) + k (3 g/l) + N in the form of urea (2 g/l) is recommended.

CONCLUSION

Foliar spraying increased the yield in T3, T2, and T1 treatments (trees with 50% of their flowers removed) compared to the control by by 68%, 64% and 53%, respectively. It is concluded that The yield reduction caused by flower drops in pomegranate trees can be compensated by foliar spraying, especially by using Zn + K + N (T3). Additionally, our results showed that the effect of flower thinning on fruit number and weight can differ from the effect of fruit thinning on these traits.

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