Nangarhar University
International Journal of Biosciences
Received: 05 Jan 2023
Accepted after revision: 09 June 2023
Published Online: 29 June 2023

ORIGINAL ARTICLE | Vol 2, Issue 2 (2023) | e-ISSN: 2957-9988

Foliar Application of Multi-micronutrients Grade IV and Different Fruit Covering Materials: A Focus on Yield and Quality of Pomegranate (*Punica granatum* cv. Bhagwa)

Anwarulhaq Zerak[1], Hekmatullah Zaland[2], Zabihullah Safi[1], Tayebullah Zahid[1], Shafiqullah Aryan*[1], Spinghar Hanifi[3]

[1] Faculty of Agriculture, Nangarhar University, Nangarhar 2601, Afghanistan

[2] Department of Horticulture, Faculty of Agriculture, Helmand University, Helmand 3902, Afghanistan

[3] Nangarhar Agricultural and Veterinary Professional Institute, Nangarhar 2601, Afghanistan

* Corresponding author: shafiqaryan@gmail.com

ABSTRACT

Background: Foliar fertilization as a highly effective approach to regulating plant nutrition has garnered significant attention in recent years. This study determined to elucidate the impact of foliar application of micronutrients grade IV and pre-harvest fruit covering bags on the quality and yield of pomegranate cv. Bhagwa.

Materials and Methods: Micronutrients grade IV was applied to foliage at the time of flowering and three weeks after first flowering with 0.5%, 1.0%, and 1.5% concentrations. Thereafter, the completely set fruits of pomegranates were covered in a newspaper bag, brown paper bag, white paper bag, non-woven bag, and non-covered fruits left as control treatment.

Findings: The results revealed that significantly ($P<0.05$) higher amount of fruit yield (ton/hectare), fruit retention, total sugar (%), and reducing sugar (%) was observed with the application of multi-micronutrients at 1.0% level concentration. In addition, all the aforementioned parameters showed significantly ($P<0.05$) higher values at 1.0% multi-micronutrients with the interaction of brown paper bags covering materials.

Conclusion: To conclude, fruit covering materials and the application of nutrients substantially influence the yield and quality of pomegranate.

Keywords: Chemical attributes, covering materials, foliar application, fruit quality, micronutrients, pomegranate

INTRODUCTION

Pomegranate is well adapted to Mediterranean climate conditions and is widely cultivated in Spain, India, Egypt, the USA, Afghanistan, etc. (Davarpanah et al., 2018). It is rich in polyphenols, antioxidants, and organic compounds consumed in either fresh fruit or processed forms (Zahedi et al., 2019). However, the quality and yield of pomegranates are substantially affected by soil conditions, tree nutrient management, and irrigation. The deficiency of micronutrients depends on soil type and available form of the nutrient (Dhillon et al., 2011). According to Davarpanah et al. (2016), essential elements are required for better plant growth, reproduction, fruit yield, and quality. Therefore, the supplemental addition of nutrients into the soil to improve soil fertility is necessary for sustainable agriculture production (Barker and Pilbeam, 2021). In pomegranates, the availability of microelements directly influences fruit set, retention, and quality. Zinc, in particular, plays a vital role in activating various enzymes such as dehydrogenases, aldolases, isomerases, transphosphorylases, as well as RNA and DNA polymerases (Mirzapour and Khoshgoftarmanesh, 2012; Singh et al., 2020).

Boron is one of the essential constituents of the cell membrane and essential for cell division. It also acts as a regulator of the potassium/calcium ratio in plants, which helps in the absorption of nitrogen and sugar translocation increasing the fruit size and yield (Lindsay, 1972). In addition, copper, manganese, and potash are involved in physiological processes during fruit growth. Also, the individual foliar application of iron increased the yield of pomegranate by 20 – 31% (Davarpanah et al., 2020).

In pomegranates, fruit cracking, internal breakdown, and sunburn are major physiological disorders that catastrophically produce low and poor-quality production (Singh et al., 2020). Hence, physical protection through covering/bagging the fruits is required to mitigate the environmental stresses. The red-colored bagging of pomegranate fruits minimized the cracking and bacterial blight infection by 66% and 78%, respectively (Asrey et al., 2020a; Yuan et al., 2012), and substantially decreased the peel sunburn. During fruit development, bagging reduces the chance of physical damage while improving pomegranate's color, yield, and quality (Griñán et al., 2019).

The application of micronutrients as a supplemental additive for trees and bagging pomegranate fruits are rarely studied. In this study, we hypothesized that fruit bagging of pomegranates combined with the foliar application of micronutrients might improve pomegranate yield and quality.

MATERIALS AND METHODS

Plant materials, Multi-micronutrients, and Covering Materials

This research was conducted at Lal Baug, Fruit Research Station, Junagadh Agricultural University, Junagadh, India, in 2020. The experiment was based on a factorial randomized block design with three replications (each replication contained 5 trees). The foliar application of micronutrient grade IV (containing Zinc, Boron, Iron, Copper, and Manganese) in different concentrations as 0.5% (M1), 1.0% (M2), and 1.5% (M3) were applied on five years aged pomegranate trees of Bhagwa cultivar. The micronutrient grade IV was applied at the flowering stage and three weeks after flowering. After completion of the fruit set, the bagging materials included: non-covered (C1) fruits as control, newspaper bags (C2), brown paper bags (C3), white paper bags (C4), and non-woven bags (C5).

Fruit Chemical and Physical Properties

The number of male flowers per plant, number of hermaphrodite flowers per plant, number of intermediate flowers per plant, fruit yield per plant, total sugar, reducing sugar, non-reducing sugar, and total soluble solids (TSS) were measured as described by Davarpanah et al., (2016a).

Data Analysis

The data were analyzed based on two-way analysis of variance (ANOVA) using language R 3.6.2 statistical software. Differences among the treatments were separated using Tukey’s test at $\alpha = 0.05$ significance level. The spacing between plants within a row and between rows was 5 m and 6 m, respectively. All fruits were harvested from the designated trees, and the yield was subsequently calculated in tons per hectare.

RESULTS

Effect of Micronutrient Foliar Application and Covering Materials on Fruit Yield, Fruit Retention, and Flowering Characteristics

There was a significant ($P<0.05$) increase in pomegranate yield with the foliar application of micronutrients grade IV and using covering materials in all treatments as compared to control, except C5 treatment in all three concentrations (Figure 1). The highest fruit yield was observed in M2 concentration compared to M1 and M3. Moreover, the increase of fruit yield in M2 concentration with different covering materials was significantly higher with respect to its control (C1), and the difference was 47.4%, 20.8%, and 12.6% in C3, C4, and C2, respectively.

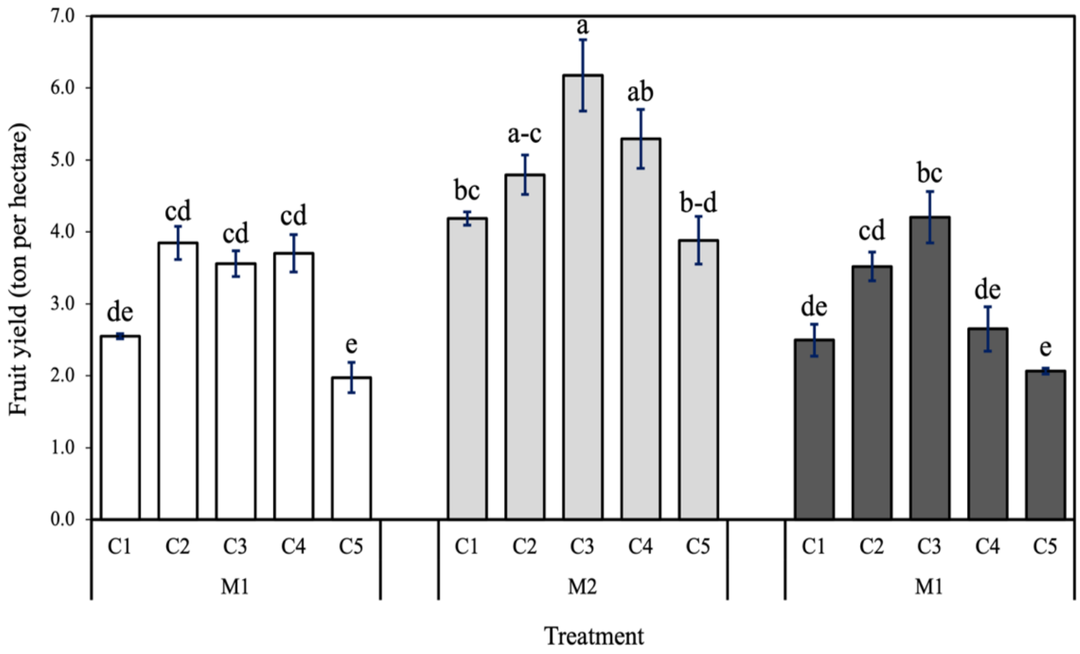

Figure 1. Integrated effects of foliar application of multi-micronutrient grade IV and different covering bags on fruit yield of pomegranate cv. Bhagwa. Vertical error bars denote the standard error. Different letters indicate significant differences among five treatments (covering bags) for each concentration at the $P<0.05$ level. M and C abbreviation denotes micronutrient grade IV and covering bags, respectively.

The results revealed that foliar application of multi-micronutrient grade IV had diverse effects on fruit retention, which was substantially different based on concentration rate. At the same time, there was a highly significant difference ($P<0.001$) with the covering materials. The highest fruit retention value was observed in M2 concentration with C3 covering bags, as shown in Table 1. In contrast, the lowest fruit retention was observed in C5 covering materials concerning all multi-micronutrient concentrations. In addition, the number of male flowers, hermaphrodite flowers, and intermediate flowers per tree didn't significantly differ under various covering materials and in the interaction between multi-micronutrients and covering materials. However, still, there were differences in the aforementioned parameters under the foliar application of micronutrients (Table 1).

Table 1. Effect of foliar application of multi micronutrient grade IV and different fruit covering bags on fruit retention and flower characteristics of pomegranate cv. Bhagwa.

Micronutrient grade IV (%)	Covering materials	Fruit retention	No. of male flowers/tree	No. of hermaphrodite flowers/tree	No. of intermediate flowers/tree
M1	C1	70.5 ± 1.3 b-d	33.1 ± 2.20 ab	120.4 ± 2.70 ab	8.4 ± 0.87 ab
	C2	62.7 ± 1.1 d-f	24.7 ± 1.89 b	87.5 ± 5.63 b	6.9 ± 0.99 b
	C3	82.0 ± 1.3 a-c	35.1 ± 2.42 ab	121.2 ± 2.21 ab	9.7 ± 0.53 ab
	C4	67.3 ± 3.5 c-e	38.6 ± 2.42 ab	119.3 ± 8.36 ab	9.2 ± 0.92 ab
	C5	48.3 ± 3.6 e	36.8 ± 3.37 ab	117.7 ± 7.14 ab	8.9 ± 0.45 ab
M2	C1	60.8 ± 0.7 d-f	37.7 ± 6.86 ab	94.2 ± 3.55 b	9.9 ± 0.14 ab
	C2	68.9 ± 2.5 b-e	38.4 ± 1.68 ab	107.4 ± 3.21 ab	10.0 ± 0.49 ab
	C3	85.5 ± 1.3 a	38.8 ± 2.34 ab	101.0 ± 5.17 ab	10.5 ± 0.70 ab
	C4	69.2 ± 1.30 b-e	39.4 ± 1.10 ab	106.1 ± 4.14 ab	10.5 ± 0.49 ab
	C5	64.6 ± 5.4 d-e	42.7 ± 2.03 a	104.3 ± 6.52 ab	10.3 ± 0.81 ab
M3	C1	65.2 ± 3.9 d-e	33.7 ± 1.29 ab	105.3 ± 5.13 ab	8.8 ± 1.20 ab
	C2	72.1 ± 4.0 a-d	35.9 ± 3.48 ab	123.8 ± 5.04 ab	10.1 ± 0.54 ab
	C3	82.3 ± 1.7 ab	35.4 ± 0.37 ab	125.7 ± 3.11 ab	10.6 ± 0.49 a
	C4	72.9 ± 1.8 a-d	36.8 ± 2.53 ab	126.4 ± 3.79 ab	10.6 ± 0.52 ab
	C5	55.1 ± 3.5 de	28.2 ± 3.17 ab	111.3 ± 5.62 a	7.3 ± 0.85 ab
Micronutrient		ns	**	**	**
Covering materials		***	ns	ns	*
Micronutrient × Covering		**	ns	ns	ns

The data are represented as mean and followed by the standard error. Different letters indicate significant differences among five treatments (covering bags) for each concentration at the $P<0.05$ level. ***$P<0.001$, **$P<0.01$, *$P<0.05$, and ns: not significant. M and C abbreviation denotes micronutrient grade IV and covering bags, respectively.

The foliar application of micronutrient grade IV significantly ($P<0.001$) affected the total sugar percentage with the various concentrations. However, the covering materials also showed significant ($P<0.05$) differences under different covering bags. The M2 concentration increased total sugar as compared to M1 and M3 treatments. In the interaction of M2 and covering materials, C3 treatment increased the total sugar amount, followed by C2 and C1.

The statistical analysis of data showed that the foliar application of multi-micronutrient grade IV had a significant ($P<0.001$) difference. At the same time, there was no difference between the utilization of covering materials and its interaction with micronutrients. Furthermore, the highest values reducing sugar were observed in the M2 which received C3 bagging material treatment compared to M1 and M3, as shown in Table 2. In contrast, non-reducing sugar increased in M1 concerning C2 covering materials (Table 2).

Table 2. Effect of foliar application of multi micronutrient grade IV and different fruit covering bags on biochemical attributes and taste of pomegranate cv. Bhagwa.

Micronutrient grade IV (%)	Covering materials	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	TSS (°Brix)
M1	C1	12.0 ± 0.34 b	10.2 ± 0.15 ab	2.1 ± 0.10 ab	13.4 ± 0.26 b-d
	C2	12.2 ± 0.25 ab	10.7 ± 0.22 ab	2.1 ± 0.13 a	13.3 ± 0.09 b-d
	C3	12.0 ± 0.07 b	10.7 ± 0.15 ab	1.3 ± 0.10 a-c	14.1 ± 0.44 b
	C4	11.7 ± 0.21 b	10.6 ± 0.30 ab	1.1 ± 0.08 c	15.6 ± 0.30 a
	C5	12.1 ± 0.12 b	10.7 ± 0.17 ab	1.3 ± 0.26 a-c	13.4 ± 0.26 b-d
M2	C1	12.6 ± 0.12 ab	10.9 ± 0.23 ab	1.7 ± 0.13 a-c	14.1 ± 0.20 b
	C2	12.6 ± 0.19 ab	10.8 ± 0.25 ab	1.8 ± 0.08 a-c	13.9 ± 0.47 b
	C3	13.6 ± 0.20 a	11.6 ± 0.34 a	1.7 ± 0.32 a-c	12.4 ± 0.12 cd
	C4	12.5 ± 0.18 ab	10.8 ± 0.18 ab	1.6 ± 0.24 a-c	13.8 ± 0.15 b
	C5	12.6 ± 0.20 ab	10.8 ± 0.27 ab	1.8 ± 0.13 a-c	13.1 ± 0.06 b-d
M3	C1	12.1 ± 0.16 ab	10.5 ± 0.11 ab	1.6 ± 0.06 a-c	12.1 ± 0.06 d
	C2	11.5 ± 0.47 b	10.0 ± 0.51 b	1.6 ± 0.10 a-c	13.6 ± 0.10 bc
	C3	12.1 ± 0.55 b	10.1 ± 0.61 ab	1.9 ± 0.07 a-c	13.6 ± 0.50 bc
	C4	11.2 ± 0.41 b	10.0 ± 0.41 ab	1.2 ± 0.20 bc	13.5 ± 0.09 bc
	C5	11.4 ± 0.27 b	9.8 ± 0.25 b	1.6 ± 0.20 a-c	12.2 ± 0.12 d
Micronutrient		***	***	ns	***
Covering materials		*	ns	**	***
Micronutrient × Covering		ns	ns	*	***

The data are represented as mean and followed by the standard error. Different letters indicate significant differences among five treatments (covering bags) for each concentration at the P<0.05 level. ***P<0.001, **P<0.01, *P<0.05, and ns: not significant. M and C abbreviation denotes micronutrient grade IV and covering bags, respectively.

DISCUSSION

The result of this study revealed that foliar application of multi-micronutrient grade IV increased the yield of pomegranate, as shown in Figure 1. In addition, a small amount of multi-micronutrient grade IV is needed to produce enough fruits. Therefore, the application of M2 (1%) showed higher fruit yield as compared to M1 (0.5%) and M3 (1.5%). These results were similar to those obtained by Obaid et al., (2013). Similarly, different fruit-covering materials increased the yield of pomegranate, as demonstrated in figure 1. Covering materials can protect fruits from different physical, mechanical, and chemical injuries; therefore, brown paper bags (C3) reported high fruit yield compared to other covering materials.

The result pertaining to variation in fruit retention was found non-significant as influenced by the application of multi-micronutrient grade IV. Whereas fruit-covering bags brought a significant effect on fruit retention, which is depicted in Table 1. Similarly, brown paper bags (C3) noticed maximum fruit retention, followed by white paper bags (C4) as compared to other covering materials. As we know that brown paper bags are strong against the sun, birds, and damaging environmental factors, compared to other covering bags, so it gives good results in fruit retention. The result of brown paper might be due to its effect of brown color for maintaining the inner temperature and acting as a repellent for birds, insects, etc. These results are also supported by (Ali et al., 2021; Feng et al., 2014) in apples, and (Asrey et al., 2020b) in pomegranates.

The variation due to micronutrient grade IV on the number of male flowers, number of hermaphrodite flowers, and intermediate flowers per tree were significant. A significantly higher number of male flowers, number of hermaphrodite flowers, and number of intermediate flowers per tree were recorded with foliar application of micronutrient grade IV M2 (1%) compared to M1 (0.5%) and M3 (1.5%). The variation due to different fruit covering bags was observed non-significant effect on the number of male and hermaphrodite flowers per tree except intermediate flowers per tree. These findings are in agreement with Maity et al., (2021). The increased rate due to micronutrients might be due to Zn, which induces photosynthetic activity and produces more biomass. Zn aid in boosting the synthesis of auxin in the plant. Several other micronutrients activate the enzymes, which help in protein and carbohydrate metabolism, which increases the different flowers per tree. Micronutrient also contains boron which might have increased the fruit percentage. Metabolism of hormones such as auxin (IAA) and tryptophan increases with an increase in Zn concentration (Feng et al., 2014).

Variations in total sugar, reducing sugar, and TSS were significantly diverse by application of micronutrient grade IV. The maximum total sugar and reducing sugar were observed in micronutrient grade IV M2 (1%). However, TSS was higher in micronutrient grade IV M1 (0.5%) compared to M3 (1.5%), and non-reducing sugar was non-significant by application of micronutrient grade IV. In addition, the total sugar, non-reducing sugar, and TSS were significantly influenced by the fruit-covering materials except for reducing sugar which was non-significant in fruit-covering materials. Therefore, brown paper bags recorded higher total sugar, non-reducing sugar, and TSS than others. Zinc's involvement in various enzyme reactions, such as carbohydrate transformation, hexokinase activity, and cellulose formation, may contribute to variations in chemical parameters. Additionally, zinc's impact on zymohexose can influence changes in sugar levels. On the other hand, iron is associated with the development of flavor proteins, further highlighting its significance in this context. Furthermore, adequate zinc improves the auxin content, which catalyzes oxidation-reduction processes in plants (Singh et al., 2020). The increase in TSS is thought to be due to borate ion associated with the cell membrane, where it could be complex with sugar molecules and facilitate its passage across the membrane which might be the reason for increased total soluble solids (Ramegowda, 2019).

CONCLUSION

The results of this study indicated that foliar application of multi-micronutrient grade IV and covering bag prominently affected the yield and quality of pomegranate. Among different concentrations of multi-micronutrients, the 1% concentration showed the highest fruit yield, fruit retention, total sugar, and proper reducing sugar amount. In addition, the brown paper covering bags also showed the highest values of the parameters above concerning the interaction of a 1% concentration level of multi-micronutrients.

CONFLICT OF INTEREST

The authors declared no conflict of interest.

REFERENCES

1. Ali, M. M., Anwar, R., Yousef, A. F., Li, B., Luvisi, A., de Bellis, L., Aprile, A., & Chen, F. (2021). Influence of Bagging on the Development and Quality of Fruits. *Plants*, *10*(2), 1–17. https://doi.org/10.3390/PLANTS10020358
2. Asrey, R., Kumar, K., Sharma, R. R., & Meena, N. K. (2020a). Fruit bagging and bag color affects physico-chemical, nutraceutical quality and consumer acceptability of pomegranate (Punica granatum L.) arils. *Journal of Food Science and Technology*, *57*(4), 1469–1476. https://doi.org/10.1007/S13197-019-04182-X/METRICS

3. Asrey, R., Kumar, K., Sharma, R. R., & Meena, N. K. (2020b). Fruit bagging and bag color affects physico-chemical, nutraceutical quality and consumer acceptability of pomegranate (Punica granatum L.) arils. *Journal of Food Science and Technology*, *57*(4), 1469–1476. https://doi.org/10.1007/S13197-019-04182-X/METRICS
4. Barker, A. v., & Pilbeam, D. J. (2021). *Handbook of plant nutrition*. https://www.routledge.com/Handbook-of-Plant-Nutrition/Barker-Pilbeam/p/book/9781032098630
5. Davarpanah, S., Tehranifar, A., Abadía, J., Val, J., Davarynejad, G., Aran, M., & Khorassani, R. (2018). Foliar calcium fertilization reduces fruit cracking in pomegranate (Punica granatum cv. Ardestani). *Scientia Horticulturae*, *230*, 86–91. https://doi.org/10.1016/J.SCIENTA.2017.11.023
6. Davarpanah, S., Tehranifar, A., Davarynejad, G., Abadía, J., & Khorasani, R. (2016a). Effects of foliar applications of zinc and boron nano-fertilizers on pomegranate (Punica granatum cv. Ardestani) fruit yield and quality. *Scientia Horticulturae*, *210*, 57–64. https://doi.org/10.1016/j.scienta.2016.07.003
7. Davarpanah, S., Tehranifar, A., Davarynejad, G., Abadía, J., & Khorasani, R. (2016b). Effects of foliar applications of zinc and boron nano-fertilizers on pomegranate (Punica granatum cv. Ardestani) fruit yield and quality. *Scientia Horticulturae*, *210*, 57–64. https://doi.org/10.1016/J.SCIENTA.2016.07.003
8. Davarpanah, S., Tehranifar, A., Zarei, M., Aran, M., Davarynejad, G., & Abadía, J. (2020). Early Season Foliar Iron Fertilization Increases Fruit Yield and Quality in Pomegranate. *Agronomy 2020, Vol. 10, Page 832*, *10*(6), 832. https://doi.org/10.3390/AGRONOMY10060832
9. Dhillon, W. S., Gill, P.P.S., & Singh N.P. (2011). effect of nitrogen, phosphorus and potassium fertilization on growth, yield and quality of pomegranate “KANDHARI.” *Acta Horticulturae*, *890*, 327–332. https://doi.org/10.17660/ACTAHORTIC.2011.890.45
10. Feng, F., Li, M., Ma, F., & Cheng, L. (2014). The effects of bagging and debagging on external fruit quality, metabolites, and the expression of anthocyanin biosynthetic genes in ‘Jonagold’ apple (Malus domestica Borkh.). *Scientia Horticulturae*, *165*, 123–131. https://doi.org/10.1016/J.SCIENTA.2013.11.008
11. Griñán, I., Morales, D., Galindo, A., Torrecillas, A., Pérez-López, D., Moriana, A., Collado-González, J., Carbonell-Barrachina, Á. A., & Hernández, F. (2019). Effect of preharvest fruit bagging on fruit quality characteristics and incidence of fruit physiopathies in fully irrigated and water stressed pomegranate trees. *Journal of the Science of Food and Agriculture*, *99*(3), 1425–1433. https://doi.org/10.1002/JSFA.9324
12. Lindsay, W. L. (1972). Zinc in Soils and Plant Nutrition. *Advances in Agronomy*, *24*(C), 147–186. https://doi.org/10.1016/S0065-2113(08)60635-5
13. Maity, A., Gaikwad, N., Babu, K. D., Sarkar, A., & Patil, P. (2021). Impact of zinc and boron foliar application on fruit yield, nutritional quality and oil content of three pomegranate (Punica granatum L.) cultivars. *Https://Doi.Org/10.1080/01904167.2021.1884711*, *44*(13), 1841–1852. https://doi.org/10.1080/01904167.2021.1884711
14. Mirzapour, M. H., & Khoshgoftarmanesh, A. H. (2012). EFFECT OF SOIL AND FOLIAR APPLICATION OF IRON AND ZINC ON QUANTITATIVE AND QUALITATIVE YIELD OF POMEGRANATE. *Http://Dx.Doi.Org/10.1080/01904167.2012.733049*, *36*(1), 55–66. https://doi.org/10.1080/01904167.2012.733049
15. Obaid, E. A., Eiada, M., & Al-Hadethi, A. (2013). Effect of Foliar Application with Manganese and Zinc on Pomegranate Growth, Yield and Fruit Quality. *Journal of Horticultural Science & Ornamental Plants*, *5*(1), 41–45. https://doi.org/10.5829/idosi.jhsop.2013.5.1.273
16. Ramegowda, S. (2019). *Effect of foliar application of gibberellic acid (GA3) and nutrients on yield and quality of pomegranate (Punica granatum L.) cv. Bhagwa Nutrient management in grapes View project*. https://www.researchgate.net/publication/336058509
17. Singh, A., Shukla, A. K., & Meghwal, P. R. (2020). Fruit Cracking in Pomegranate: Extent, Cause, and Management – A Review. *Https://Doi.Org/10.1080/15538362.2020.1784074*, 1–20. https://doi.org/10.1080/15538362.2020.1784074
18. Singh, T., Singh, D., Kumar, A., Patel, A., & Bose, U. (2020). Effect of micronutrients on growth, yield and fruit quality of mango (Mangifera indica L.) cv. Dashehari. *International Journal of Chemical Studies*, *8*(6), 2055–2058. https://doi.org/10.22271/CHEMI.2020.V8.I6AC.11075

19. Yuan, Z. H., Yin, Y. L., Feng, L. J., Zhao, X. Q., Zhang, Y. X., & Hou, L. F. (2012). Evaluation of pomegranate bagging and fruit cracking in Shandong, China. *Acta Horticulturae*, *940*, 125–129. https://doi.org/10.17660/ACTAHORTIC.2012.940.15
20. Zahedi, S. M., Hosseini, M. S., Daneshvar Hakimi Meybodi, N., & Teixeira da Silva, J. A. (2019). Foliar application of selenium and nano-selenium affects pomegranate (Punica granatum cv. Malase Saveh) fruit yield and quality. *South African Journal of Botany*, *124*, 350–358. https://doi.org/10.1016/J.SAJB.2019.05.019