

Effect of Foliar Application of Nutrients on Growth, Yield and Fruit Quality of Pomegranate (*Punica granatum* L.) Cv. Bhagwa

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Authors' contributions

This work was carried out in collaboration among all authors. Author GK designed the study, performed the statistical analysis, wrote the protocol and first draft of the manuscript. Author DDS analysed the manuscript. Authors MAK and RK modified the manuscript. Authors GS and BK checked and managed the literature searches of the study. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted to study the effect of foliar application of nutrients on growth, yield and fruit quality of pomegranate (*Punica granatum* L.) cv. Bhagwa in the experimental farm of the Horticultural Research and Training Station and Krishi Vigyan Kendra Kandaghat, Solan, Dr YS Parmar University of Horticulture and Forestry Nauni, Solan, Himachal Pradesh (India), during the year 2016 - 2017. The experiment was laid out in Randomized Block Design (RBD) with four foliar applications of potassium nitrate, KNO₃ (0.5%, 1% and 1.5%); calcium chloride, CaCl₂ (0.5%, 1% and 1.5%); boric acid, H₃BO₃ (0.2%, 0.4% and 0.6%) and their combinations. The first spray was applied one month after fruit set, and the remaining three ones were applied at one month interval. Among the various treatments, significant increase in plant height, plant spread, plant volume, fruit size, fruit weight, fruit yield, total soluble solids, total sugars, reduction in fruit drop and fruit cracking were recorded with the application of KNO₃ (1%) + CaCl₂ (1%) + H₃BO₃ (0.4%). Leaf N, P, K, Ca and Mg were also significantly affected by the foliar application of KNO₃ (1%) + CaCl₂ (1%) +

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H₃BO₃ (0.4%). Therefore, the combined foliar application of KNO₃ (1%), CaCl₂ (1%) and H₃BO₃ (0.4%) was found the best treatment for the improvement of growth, yield and fruit quality of pomegranate.

Keywords: Pomegranate; cracking; growth; yield and quality.

1. INTRODUCTION

Pomegranate (*Punica granatum* L.) belongs to the family Punicaceae is a delicious and dessert table fruit of tropical and subtropical regions of the world. Its fruit has a wide consumer preference for its attractive juice, sweet-acidic, refreshing arils and also valued for its nutritional and medicinal properties. There is a growing demand for good quality fruits both for fresh and processed juice, syrup and wine. Pomegranate is native to Persia (Iran), Afghanistan and Baluchistan [1]. It is cultivated on a large scale in Spain, Morocco, Egypt, Afghanistan, Pakistan and India. In India commercial plantation of pomegranate exists in Maharashtra, Gujrat, Rajasthan, Karnataka and to a limited extent in Andhra Pradesh, Tamil Nadu, Madhya Pradesh, UP, Punjab, Haryana and Himachal Pradesh. Its wild forms are found in lower hills of Himachal Pradesh. Total area under pomegranate in India is 209 thousand hectares with annual production of 2442 thousand million tonnes [2].

During past decades, pomegranate has been introduced in the foot hills of Himachal Pradesh comprising of sub-tropical and valley areas of Shivalik hills (mainly in mid-hill areas of Solan, Sirmour, Shimla, Chamba, Mandi, Kullu and Kangra districts), which holds tremendous scope of pomegranate cultivation. In Himachal Pradesh total area under pomegranate accounted for 2771 hectares with an annual production of 3215 tonnes [3]. The quality of fruits produced in this region is inferior because of lower summer temperatures coupled with higher humidity during the later stage of fruit development. Pre-harvest fruit cracking associated with soil moisture fluctuation in summer is another problem, which further causes substantial economic loss to the growers. The primary objective was to increase the productivity of quality fruits of pomegranate in this region. The 'Bhagwa' cultivar of pomegranate is presently under commercial cultivation in the state. This cultivar is a heavy yielder and possesses highly desirable fruit characters. This cultivar matures in 170-180 days. Fruits are medium to big in size, attractive, smooth, glossy with dark saffron

thick skin and arils are sweet in taste with red colour and hence fetch a very good price in the market. It is suitable for long distance market as it has thick rind and better keeping quality. The growth habit of tree is spreading type [4]. Considering all these attributes, 'Bhagwa' cultivar is good for commercial cultivation in pomegranate growing regions of Himachal Pradesh.

Foliar application of plant nutrients have various beneficial effects on pomegranate, therefore, foliar sprays of nutrients in adequate quantity should be applied at appropriate time for optimum growth, yield, fruit quality and control of fruit cracking. Foliar fertilization has the advantage of uniform distribution of fertilizer materials and quick response to the applied nutrients.

Potassium is involved in a number of physiological processes, activation of numerous enzymes and regulation of the cation-anion balance [5]. Potassium promotes the translocation of photosynthates (sugars) for plant growth and storage in fruits and roots. Calcium has a major role in the formation of the cell wall membrane and its plasticity, affecting normal cell division by maintaining cell integrity and membrane permeability. Calcium is an activator of several enzyme systems in protein synthesis and carbohydrate transfer. Boron has been associated with lignin synthesis activity of certain enzymes, seed and cell wall formation, and sugars transport.

Keeping in view the above importance, the present study was conducted to find out the effect of foliar application of nutrients and their combinations on growth, yield and fruit quality of pomegranate cv. Bhagwa.

2. MATERIALS AND METHODS

The experiment was conducted in the experimental farm of Horticultural Research and Training Station and Krishi Vigyan Kendra Kandaghat, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India situated at an elevation

of 1,344 m above mean sea level at 30° 58'1.339"N latitude and 77°5'44.626"E longitude during the year 2016 - 2017. The pomegranate plants of cv. Bhagwa selected for the experiment were eight years old planted at a spacing of 4m x 4 m. The experiment was laid out in Randomized Block Design (RBD) with thirteen treatment combinations such as T₁: KNO₃ (0.5%), T₂: KNO₃ (1%), T₃: KNO₃ (1.5%), T₄: CaCl₂ (0.5%), T₅: CaCl₂ (1%), T₆: CaCl₂ (1.5%) T₇: H₃BO₃ (0.2%), T₈: H₃BO₃ (0.4%), T₉: H₃BO₃ (0.6%), T₁₀: KNO₃ (0.5%) + CaCl₂ (0.5%) + H₃BO₃ (0.2%), T₁₁: KNO₃ (1%) + CaCl₂ (1%) + H₃BO₃ (0.4%), T₁₂: KNO₃ (1.5%) + CaCl₂ (1.5%) + H₃BO₃ (0.6%) and T₁₃: Control with three replications. Treatments were applied as foliar sprays and number of applications was four. First spray was applied one month after fruit set and rest three sprays were applied one month intervals repeated with same treatments and concentration. One tree was sprayed with each treatment per replication in the form of gram per litre.

The observations were taken in respect of vegetative growth, yield, quality, and leaf nutrient content of pomegranate. The vegetative growth was recorded once before the start of the experiment and again at the termination of the experiment. Fruit yield was determined on the basis of total weight of fruits harvested from the trees under each treatment and was expressed as (kg pL⁻¹). To measure fruit size, length and breadth, five randomly selected fruits were measured with the help of digital vernier calliper. Fruit length and breadth were calculated and expressed in centimetres. To record fruit weight, five randomly selected fruits were weighed with the help of a weighing pan and average fruit weight was calculated and expressed as weight per fruit in grams. Fruit cracking was calculated by counting the number of fruits cracked out of total number of fruits at the time of harvest and were expressed in per cent. Total sugars and reducing sugars were determined by the method suggested by [6], using Fehling's A and B solutions. For the estimation of leaf nitrogen, leaf samples were digested in concentrated sulphuric acid by adding digestion mixture (potassium sulphate 400 parts, copper sulphate 20 parts, mercuric oxide 3 parts and selenium powder 1 part). In the case of P, K, Ca and Mg leaf samples were digested in a diacid mixture containing nitric acid and perchloric acid in the ratio of 4:1 [7]. Mature and disease free leaf samples of current season's growth were collected from around the periphery of the trees on 15th August.

The data generated from present investigations were appropriately computed, tabulated and analysed by using MS-Excel and OPSTAT programme. The data were subjected to analysis of variance as outlined by [8] for Randomized Block Design. One-way analysis of variance was performed to determine significance of difference between the treatment means at 5 per cent level of significance.

3. RESULTS AND DISCUSSION

3.1 Vegetative Growth

Foliar application of different nutrients alone or in combination resulted in significant increase in plant height, spread and volume. The application of KNO₃ treatment (1.0%) + CaCl₂ (1.0%) + H₃BO₃ (0.4%) resulted in maximum increase in plant height (31.42%), plant spread (21.28%) and plant volume (5.18 m³). However, the maximum shoot extension growth (31.66 cm) was recorded in KNO₃ (1.5%) + CaCl₂ (1.5%) + H₃BO₃ (0.6%) treatment as presented in (Table 1). These findings are in line with the earlier reports of [9,10,11]. The increase in vegetative growth might be due to the fact that potassium nitrate is a good source of nitrogen. It is an essential constituent of proteins, nucleic acids, and chlorophyll which enhances the metabolic processes of plants that lead to increase in vegetative growth. The boron has its role in nitrogen metabolism, hormone movement and cell division, which resulted in more plant growth.

3.2 Fruit Yield

The foliar applications of different nutrients alone or in combination also increased the fruit yield significantly as shown in (Table 1). The highest fruit yield (32.96 kg/plant) was recorded with foliar spray of KNO₃ (1%) + CaCl₂ (1%) + H₃BO₃ (0.4%) treatment followed by KNO₃ (1.5%) + CaCl₂ (1.5%) + H₃BO₃ (0.6%). The increase in fruit yield with the foliar application of nutrients may be attributed to increased fruit size, fruit weight and minimum fruit drop. In addition, more cell division, cell elongation and translocation of photosynthates and metabolites from leaves to the developing fruits which resulted in higher fruit yield. The highest fruit yield recorded by foliar spray of KNO₃, CaCl₂ and H₃BO₃, may be attributed to better uptake and mobilization of nutrients to the sink leading to better fruit development. These findings are also supported by earlier reports of [12] with the application of KNO₃ (2%) in pomegranate, [13] in apple with

the application of H_3BO_3 (0.1%) + CaCl_2 (0.4%) and [14] in pomegranate with (0.4%) boric acid in combination with zinc sulphate also increased fruit yield significantly.

3.3 Fruit Size and Weight

The maximum fruit length (9.03 cm) and fruit weight (383.88 g) were recorded with the spray of KNO_3 (1%) + CaCl_2 (1%) + H_3BO_3 (0.4%). However, the maximum fruit diameter (9.28 cm) was recorded with the spray of KNO_3 (1.5%) + CaCl_2 (1.5%) + H_3BO_3 (0.6%) has shown in (Table 1 and Table 2). The possible reason for increase in the fruit length and diameter might be due to the fact that mineral nutrients have an indirect role in hastening the process of cell division and cell elongation due to which the size of fruit might have improved. The increase in fruit weight might be attributed to rapid increase in the size of cells or it is also due the fact that foliar application of boron increased the fruit weight by maintaining the level of auxins in various parts of the fruits which helped in increasing the fruit growth [15]. These findings are in conformity with those of [16,17] in apple with the application of K and B.

3.4 Fruit Cracking

In the present investigation, different nutrients applied alone or in combination have a significant effect on fruit cracking (Table 1). The minimum fruit cracking (1.75%) was obtained with the spray of intermediate level of KNO_3 (1%) + CaCl_2 (1%) + H_3BO_3 (0.4%). These results are in agreement with those of [18,19,20] they recorded less fruit cracking in pomegranate by using 0.2% boric acid. The reduction in fruit cracking may be attributed to the physiological role of boron in the synthesis of pectic substances in the cell wall, which strengthened the tissues and prevented fruit cracking. Role of calcium in binding the tissues especially in the middle lamella play an important role in reducing the fruit cracking [21]. This can also be attributed to a synergism of boron that may helps in calcium metabolism in cell wall [22].

3.5 Juice Content

In the present investigation, application of different nutrients alone or in combination had a significant effect on the increase in juice content of fruits (Table 2). A significant increase in juice content (71.33%) was recorded in fruits produced by plants sprayed with KNO_3 (1.5%). The results are in line with those of [23] who recorded an

increase in the juice content of pomegranate by the application of potassium nitrate. Increase in juice content also might be because of smaller seeds and more juice in the variety 'Bhagwa' [24].

3.6 Total Soluble Solids (TSS) and Titratable Acidity

The results of the present study revealed that application of different nutrients alone or in combination had a significant effect on TSS and titratable acidity (Table 2). TSS content (13.50 °Brix) was improved with the treatment combination of KNO_3 (1%) + CaCl_2 (1%) + H_3BO_3 (0.4%). [25] also observed an increase in TSS with the application of calcium in apple and [26] in 'Red Delicious' apple by using calcium chloride and boric acid. The highest TSS recorded by foliar application of nutrients might be due to lesser utilization of sugars in metabolic processes as a result of reduced respiration [27]. Increase in total soluble solids might be due to the fact that boron helped in trans-membrane sugar transport. Minimum titratable acidity (0.36%) in the present study was recorded with the application of H_3BO_3 0.4%. These results are in agreement with the findings of [28], who also recorded reduction in fruit acidity with the application of 0.4% borax in litchi.

3.7 Total, Reducing and Non-reducing Sugars

In the present study, total, reducing and non-reducing sugars were significantly affected by foliar nutrient applications alone or in combination (Table 2). Higher content of total sugars (12.85%) and non-reducing sugars (2.33%) were recorded with the treatment of intermediate level of KNO_3 , CaCl_2 and H_3BO_3 in combination i.e. KNO_3 (1%) + CaCl_2 (1%) + H_3BO_3 (0.4%). However, the higher content of reducing sugars (10.58%) was observed in treatment KNO_3 (1.5%). The increase in the sugars content might be due to rapid translocation of sugars from leaves to the developing fruits. Boron facilitated sugar transport within the plant. It was also reported that borate reacted with sugars to form a sugar-borate complex. Boron also act as a switcher in the degradation of glucose either by glycolysis or by pentose sugar path way [29]. Increase in leaf K concentration also enhances the rate of photosynthesis and this could be one of the reasons for increasing sugars content in the fruits.

Table 1. Effect of foliar application of nutrients on vegetative growth, fruit size, fruit yield and fruit cracking in pomegranate cv. bhagwa

Treatments	Increase in plant height (%)	Increase in plant spread (%)	Annual shoot extension growth (cm)	Increase in Plant volume (m ³)	Yield (kg/plant)	Fruit cracking (%)	Length (cm)	Breadth (cm)
T ₁ : KNO ₃ (0.5%)	29.41	20.07	28.33	4.67	26.23	4.61	7.96	8.55
T ₂ : KNO ₃ (1%)	29.87	20.42	29.00	4.73	26.66	4.39	7.89	8.61
T ₃ : KNO ₃ (1.5%)	29.97	20.96	30.00	4.99	27.04	4.24	8.17	8.73
T ₄ : CaCl ₂ (0.5%)	27.19	18.89	25.66	2.86	27.48	3.85	8.25	8.80
T ₅ : CaCl ₂ (1%)	27.93	19.67	25.66	3.18	30.03	3.09	8.54	8.87
T ₆ : CaCl ₂ (1.5%)	28.34	19.97	27.66	3.68	30.37	3.16	8.64	8.95
T ₇ : H ₃ BO ₃ (0.2%)	28.83	20.39	27.33	3.71	27.26	3.62	7.98	8.83
T ₈ : H ₃ BO ₃ (0.4%)	28.95	20.45	27.33	3.72	28.24	2.34	8.67	8.94
T ₉ : H ₃ BO ₃ (0.6%)	29.73	20.62	27.33	4.46	29.30	2.79	8.81	9.14
T ₁₀ : T ₁ + T ₄ + T ₇	30.25	20.80	29.66	4.93	31.29	2.64	8.69	9.00
T ₁₁ : T ₂ +T ₅ +T ₈	31.42	21.28	30.33	5.18	32.96	1.75	9.03	9.18
T ₁₂ : T ₃ + T ₆ +T ₉	30.84	21.03	31.66	5.04	32.64	1.95	8.89	9.28
T ₁₃ : Control	26.23	16.58	22.00	2.37	23.28	5.49	7.57	8.26
CD _{0.05}	1.61	0.58	2.97	0.19	0.41	0.25	0.29	0.25

Table 2. Effect of foliar application of nutrients on physico-chemical characteristics of fruit and leaf nutrient content of pomegranate cv. bhagwa

Treatments	Fruit weight (g)	Juice content (%)	TSS (°Brix)	Titratable acidity (%)	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T ₁ : KNO ₃ (0.5%)	312.32	65.73	12.53	0.45	11.60	9.44	2.05	1.75	0.15	1.49	1.72	0.61
T ₂ : KNO ₃ (1%)	331.49	67.83	12.60	0.43	12.17	10.41	1.67	1.80	0.17	1.50	1.66	0.60
T ₃ : KNO ₃ (1.5%)	344.16	71.33	13.10	0.43	12.23	10.58	1.56	1.81	0.17	1.78	1.80	0.56
T ₄ : CaCl ₂ (0.5%)	312.99	65.50	12.23	0.46	10.92	9.33	1.51	1.62	0.14	1.37	1.91	0.57
T ₅ : CaCl ₂ (1%)	316.66	67.67	12.40	0.46	11.26	9.62	1.55	1.69	0.14	1.48	2.12	0.61
T ₆ : CaCl ₂ (1.5%)	347.00	69.10	12.60	0.45	11.73	9.56	2.06	1.73	0.16	1.49	2.29	0.55
T ₇ : H ₃ BO ₃ (0.2%)	320.33	66.00	12.56	0.45	11.56	9.76	1.71	1.56	0.18	1.31	1.67	0.64
T ₈ : H ₃ BO ₃ (0.4%)	333.00	68.33	12.60	0.36	11.73	9.56	2.06	1.60	0.19	1.32	1.76	0.62
T ₉ : H ₃ BO ₃ (0.6%)	352.16	69.20	12.70	0.41	11.99	9.81	2.07	1.62	0.19	1.40	1.71	0.61
T ₁₀ : T ₁ + T ₄ + T ₇	346.32	69.33	12.90	0.40	12.07	9.97	1.99	1.78	0.20	1.50	2.03	0.64
T ₁₁ : T ₂ +T ₅ +T ₈	383.88	69.97	13.50	0.39	12.85	10.39	2.33	1.82	0.22	1.58	2.23	0.66
T ₁₂ : T ₃ + T ₆ +T ₉	371.16	70.73	13.16	0.38	12.29	10.07	2.10	1.92	0.21	1.75	2.16	0.65
T ₁₃ : Control	290.66	63.33	11.60	0.50	10.66	9.23	1.35	1.54	0.12	0.98	1.47	0.51
CD _{0.05}	19.39	2.14	0.42	0.03	0.29	0.11	0.31	0.11	0.04	0.26	0.12	0.03

3.8 Leaf Nutrient Composition

It is clear from the data presented in (Table 2) that the foliar application of different nutrients alone or in combination exerted a significant effect on nitrogen, phosphorus and potassium content of leaf. The maximum leaf nitrogen (1.92%) was found in the trees treated with KNO₃ (1.5%) + CaCl₂ (1.5%) + H₃BO₃ (0.6%). In case of phosphorus, treatment of KNO₃ (1%) + CaCl₂ (1%) + H₃BO₃ (0.4%) significantly improved leaf phosphorus (0.22%). Treatment KNO₃ (1.5%) recorded the maximum leaf potassium (1.78%) content. While the minimum leaf nitrogen (1.54%), leaf phosphorus (0.12%), and leaf potassium (0.98%) were recorded in control. The secondary elements like calcium and magnesium in leaves varied significantly by the application of different levels of potassium, calcium and boron. Maximum leaf calcium (2.29%) was recorded in the treatment CaCl₂ (1.5%) and leaf magnesium concentration (0.66%) was recorded to be highest in KNO₃ (1%) + CaCl₂ (1%) + H₃BO₃ (0.4%). However, the minimum calcium (1.47%) and magnesium (0.51%) were recorded in control. The above findings are in conformity with those of [30,31]. The above nutrients increase in the leaves might be associated with calcium and boron application which are involved in several physiological processes in plants [32]. Potassium is involved in many biochemical reactions that are essential for enzyme activities [33].

4. CONCLUSION

On the basis of results obtained from the present investigation, it is concluded that combined foliar application of KNO₃ (1%), CaCl₂ (1%) and H₃BO₃ (0.4%) (T₁₁) proved to be the best treatment. Combined application of KNO₃ (1%), CaCl₂ (1%) and H₃BO₃ (0.4%) resulted significant improvement in growth, yield, fruit quality and leaf nutrient content of pomegranate. This treatment also showed greater increase in plant height, spread, volume, with highest fruit size, fruit weight, fruit yield, TSS, total sugars, reduction in fruit cracking and increase in leaf N, P, K, Ca and Mg content in pomegranate cv. Bhagwa.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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