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EFFECT OF FOLIAR APPLICATION OF GROWTH REGULATORS, CHEMICALS AND MICRONUTRIENTS ON FLOWERING, YIELD AND FRUIT QUALITY OF POMEGRANATE (*Punica granatum* L.) CV. BHAGWA

Manohar Jakhar, Usha Shukla*, P. K. Yadav, Dipayan Sarkar and Manoj Kumar Bundela

School of Agriculture, Suresh Gyan Vihar University, Jaipur, Rajasthan, India

*Corresponding author E-mail: ushashukla174@gmail.com

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ABSTRACT

A field experiment was conducted during the Hasta bahar season of 2025-26 at the Research Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur, Rajasthan, to evaluate the effect of foliar application of growth regulators, chemicals and micronutrients on flowering behaviour, yield attributes and fruit quality parameters of pomegranate (*Punica granatum* L.) cv. Bhagwa. The experiment was laid out in a Randomized Block Design comprising eleven treatments and three replications on four-year-old plants. Treatments included Cycocel (1000 and 1500 ppm), Nitrobenzene (3 and 5 ml/lit), Salicylic acid (50 and 100 ppm), Ethrel (1% and 3%) and Potassium nitrate (1% and 2%), each combined with ZnSO₄ and boric acid at two concentration levels, along with an unsprayed control. Three foliar sprays were applied at one month before bud break, full bloom stage and one month after full bloom. Results revealed that T₂ (Cycocel 1500 ppm + 0.2% ZnSO₄ + 0.2% boric acid) recorded the maximum hermaphrodite flowers (152) and total flowers (197 per plant), while T₈ (Ethrel 3% + 0.2% ZnSO₄ + 0.2% boric acid) recorded the minimum male flowers (42). T₁₀ (Potassium nitrate 2% + 0.2% ZnSO₄ + 0.2% boric acid) proved superior for fruit physical characters, yield components and fruit yield (16.0 kg/plant), recording approximately 129% yield advantage over control. T₆ (Salicylic acid 100 ppm + 0.2% ZnSO₄ + 0.2% boric acid) recorded the highest TSS (14.9 °Brix), total sugar (11.43%) and fruit weight (280.50 g), while β-carotene was maximum under T₁₀ (0.44 mg/100 g pulp).

Key words: Hasta bahar, Cycocel, Salicylic acid, Potassium nitrate, Ethrel, Fruit quality and Yield

Introduction

Pomegranate (*Punica granatum* L.), belonging to the family Lythraceae, is one of the oldest and most important fruit crops cultivated across tropical and subtropical regions of the world. Believed to have originated in Iran and the Himalayan range, the crop has been valued since antiquity for its nutritional, medicinal and ornamental significance. Rising consumer awareness of its health-promoting bioactive compounds -including punicalagins, ellagic acid, anthocyanins and carotenoids has driven unprecedented demand and consequent expansion in area and production (Holland *et al.*, 2009). In India, pomegranate is commercially cultivated in Maharashtra, Andhra Pradesh, Karnataka,

Gujarat, Rajasthan and several other states. Rajasthan has emerged as a significant pomegranate-producing state with an area of approximately 17,160 hectares, production of 1,60,840 tonnes and productivity of 9.38 tonnes per hectare (CEIC Data, 2025a: 2025b). Under tropical conditions, pomegranate tends to flower almost continuously throughout the year. To achieve synchronized and commercially viable harvests, plants are subjected to planned rest periods commonly known as bahar treatment. Three distinct bahars are recognized: Ambe bahar (January-February), Mrig bahar (June-July) and Hasta bahar (September-October). Hasta bahar is particularly favoured in semi-arid regions like Rajasthan for its favourable post-harvest marketing season and

reduced disease incidence (Durgude *et al.*, 2019). Pomegranate produces two flower types on the same plant: functionally male flowers (bell-shaped, with rudimentary ovary) and bisexual or hermaphrodite flowers (vase-shaped, with well-developed ovary). Only hermaphrodite flowers are capable of fruit setting, making their proportion a critical determinant of yield (Chaudhari and Desai, 1993). Manipulation of floral sex expression and enhancement of hermaphrodite flower proportion through hormonal and nutritional interventions represents an important avenue for yield improvement.

Among the various production technologies available, foliar nutrition has been recognized as a rapid, efficient and economical method to supplement plant requirements for macro and micronutrients and growth-regulating substances, particularly in alkaline soils where nutrient availability is limited (Gaikwad *et al.*, 2019). Potassium enhances sugar translocation from source to sink tissues: zinc is essential for enzyme activation, auxin synthesis and photosynthesis: boron plays a critical role in pollen germination, pollen tube elongation and carbohydrate transport. Growth regulators such as Cycocel, Ethrel, Salicylic acid, Nitrobenzene and Potassium nitrate have shown beneficial effects on flowering, fruit set, fruit size and quality in several fruit crops. Despite considerable research on these inputs in other fruit crops, systematic investigations specifically addressing their integrated effects on pomegranate cv. Bhagwa under Hasta bahar conditions in Rajasthan remain limited. The present investigation was therefore undertaken to address this research gap.

Materials and Methods

The experiment was conducted during the Hasta bahar season of 2025-26 at the Research Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur, Rajasthan. The experimental orchard comprised uniform, four-year-old pomegranate plants of cv. Bhagwa, planted at a spacing of 4 m × 3 m. The soil of the experimental plot was sandy loam to loam in texture, medium in fertility, well-drained and slightly alkaline, typical of semi-arid agro-climatic conditions of the region. Hasta bahar was imposed by withholding irrigation during the first fortnight of September to induce synchronized rest and subsequent uniform bud break. Uniform pruning was carried out in all experimental plants to remove previous season's growth, dried twigs and pest- or disease-affected branches. The recommended dose of fertilizers - 625 g N, 250 g P₂O₅ and 250 g K₂O per plant along with 30 kg well-decomposed farmyard manure was applied uniformly to all plants. Three foliar sprays were applied at the

following phenological stages:

First spray: One month prior to bud break.

Second spray: At full bloom stage.

Third spray: One month after full bloom.

Standard intercultural operations, irrigation through drip system and plant protection measures were adopted uniformly across all plots throughout the crop season. Number of male flowers, hermaphrodite flowers and total flowers per plant were counted at peak flowering stage based on established morphological criteria. Fruit length and diameter were measured using Vernier calliper on five representative fruits per treatment: fruit volume was determined by water displacement method. Number of fruits per plant at fruit set (marble stage), fruit retention percentage, number of fruits retained at harvest, average fruit weight (electronic balance) and fruit yield per plant (kg/plant) were recorded. TSS was determined using Erma hand refractometer: reducing sugar and total sugar were estimated following Ranganna (1986): non-reducing sugar was calculated as (Total sugar- Reducing sugar) × 0.95 (AOAC, 1975): β-carotene was estimated spectrophotometrically at 450 nm using acetone-petroleum ether extraction. Data were subjected to analysis of variance (ANOVA) for RBD and treatment means were compared using Critical Difference (CD) at 5% level of significance.

Results and Discussion

The number of male flowers per plant varied significantly among treatments and ranged from 42 to 55 (Table 2). The minimum male flowers were recorded in T₈ (42), which was statistically at par with T₇ (44) and T₂ (45). The control T₁₁ recorded the highest male flowers (55). The reduction in male flowers under T₈ (Ethrel 3%) may be attributed to ethylene-induced changes in endogenous hormonal balance, particularly its antagonistic effect on gibberellins, which promotes differentiation of hermaphrodite flowers over staminate flowers. Wetzstein *et al.*, (2011) reported that flower type differentiation in pomegranate is hormonally regulated and influenced by growth regulators. Similarly, Cycocel in T₂ inhibits gibberellin biosynthesis, reducing vegetative growth and promoting bisexual flower development (Davarpanah *et al.*, 2016). The combined application of zinc and boron further enhanced reproductive differentiation by improving auxin synthesis and pollen viability (Hasani *et al.*, 2016). Hermaphrodite flower number varied significantly among treatments, ranging from 112 to 152 flowers per plant (Table 2). The highest number was recorded in T₂ (152), followed by T₁ (145) and T₈ (145), which were statistically at par, whereas the lowest was observed in T₁₁ (112).

Table 1: Treatment details.

Treat-ment	Treatment Details
T ₁	Cycocel 1000 ppm + 0.1% ZnSO ₄ + 0.1% boric acid
T ₂	Cycocel 1500 ppm + 0.2% ZnSO ₄ + 0.2% boric acid
T ₃	Nitrobenzene 3 ml/lit + 0.1% ZnSO ₄ + 0.1% boric acid
T ₄	Nitrobenzene 5 ml/lit + 0.2% ZnSO ₄ + 0.2% boric acid
T ₅	Salicylic acid 50 ppm + 0.1% ZnSO ₄ + 0.1% boric acid
T ₆	Salicylic acid 100 ppm + 0.2% ZnSO ₄ + 0.2% boric acid
T ₇	Ethrel 1% + 0.1% ZnSO ₄ + 0.1% boric acid
T ₈	Ethrel 3% + 0.2% ZnSO ₄ + 0.2% boric acid
T ₉	Potassiumnitrate 1% + 0.1% ZnSO ₄ + 0.1% boric acid
T ₁₀	Potassiumnitrate 2% + 0.2% ZnSO ₄ + 0.2% boric acid
T ₁₁	Control (no spray)

The superior performance of T₂ may be attributed to the anti-gibberellin action of Cycocel, which suppresses vegetative growth and promotes bisexual floral differentiation. Salicylic acid in T₆ also enhanced hermaphrodite flower production by improving photosynthetic efficiency, carbohydrate mobilization and stress tolerance. Similar findings were reported by Davarpanah *et al.*, (2016) and Wassel *et al.*, (2023). Total flower number ranged from 167 to 197 flowers per plant (Table 2). The maximum was recorded in T₂ (197), followed by T₆ (196), while the minimum was observed in T₁₁ (167). The superiority of T₂ and T₆ may be attributed to hormonal regulation, enhanced assimilate accumulation and the synergistic effects of zinc and boron on chlorophyll synthesis, enzymatic activity and meristematic growth (Hasani *et al.*, 2016; Wetzstein *et al.*, 2011).

Fruit length varied from 7.55 to 8.35 cm across treatments (Table 3). The maximum fruit length was recorded in T₁₀ (8.35 cm), followed by T₆ (8.25 cm), whereas the minimum was observed in T₁₁ (7.55 cm). The superior fruit length under T₁₀ may be attributed to the combined effect of potassium nitrate, zinc and boron. Potassium enhances cell elongation and osmotic regulation, zinc promotes auxin synthesis, and boron maintains cell wall integrity during fruit development (Chidananda *et al.*, 2020; Sharma *et al.*, 2016). Similar results have also been reported by Hamouda *et al.*, (2016) and Nikam *et al.*, (2025). Fruit diameter varied from 7.65 cm to 8.40 cm (Table 3). Maximum diameter was recorded in T₁₀ (8.40 cm), significantly superior to all others, followed by T₆ (8.30 cm). Treatments T₂ (8.20 cm) and T₈ (8.15 cm) were statistically comparable. The control recorded the minimum (7.65 cm). Greater fruit diameter under T₁₀ may be attributed to improved water uptake and maintenance of cell turgor through potassium ion balance, enhanced phloem loading by boron and improved

Table 2: Effect of foliar application on flowering behaviour of pomegranate cv. Bhagwa during Hasta bahar (2025–26).

Tr. No.	Male Flowers (No./plant)	Hermaphrodite Flowers (No./plant)	Total Flowers (No./plant)
T ₁	47	145	192
T ₂	45	152	197
T ₃	51	138	189
T ₄	49	142	191
T ₅	53	134	187
T ₆	52	144	196
T ₇	44	139	183
T ₈	42	145	187
T ₉	50	120	170
T ₁₀	48	125	173
T ₁₁	55	112	167
S.E.(m)±	1.14	4.26	3.26
C.D. at 5%	3.31	12.34	9.47

photosynthetic efficiency by zinc, ensuring greater assimilate availability for fruit development (Gaikwad *et al.*, 2019). These findings are supported by Hamouda *et al.*, (2016) and Eiada *et al.*, (2013). Fruit volume ranged from 195 ml to 300 ml (Table 3). The highest fruit volume was recorded in T₁₀ (300 ml), followed by T₆ (285 ml). Treatments T₈ (270 ml) and T₂ (265 ml) were next best and statistically at par. The minimum was recorded in T₁₁ (195 ml). The increase in fruit volume under T₁₀ reflects the cumulative effect of increased fruit length and diameter resulting from enhanced cell division and elongation due to balanced nutrition. Potassium nitrate facilitated better assimilate partitioning toward developing fruits, while zinc and boron strengthened cell walls and improved membrane integrity essential for sustained fruit expansion (Sharma *et al.*, 2016). Similar trends were reported by Hamouda *et al.*, (2016) and Eiada *et al.*, (2013).

Fruit set ranged from 55 to 85 fruits per plant (Table 4). The maximum was recorded in T₁₀ (85), followed by T₆ (80), both statistically at par and superior over remaining treatments. Treatments T₂ (72) and T₈ (75) occupied the next position. The minimum was recorded in T₁₁ (55). Higher fruit set under T₁₀ and T₆ may be attributed to improved pollen germination and pollen tube elongation facilitated by boron, enhanced auxin-mediated fruit set by zinc, and improved ovary development and fertilization efficiency by the respective growth regulators. Adequate potassium maintained cellular water potential and metabolic homeostasis during the critical fruit set phase (Dhurve *et al.*, 2018). Fruit retention varied from 56% to 75% (Table 4). Maximum retention was recorded

Table 3: Effect of foliar application on growth and yield parameters of pomegranate cv. Bhagwa during Hasta bahar (2025–26).

Tr. No.	Fruit Length (cm)	Fruit Diameter (cm)	Fruit Volume (ml)	Fruits at Fruit Set (No.)	Fruit Retention (%)	Fruits at Harvest (No.)	Avg. Fruit Weight (g)	Yield (kg/plant)
T ₁	7.87	7.90	235	62	66	41	235.10	9.6
T ₂	8.15	8.20	265	72	71	51	245.05	12.5
T ₃	7.75	7.80	212	60	63	37	225.25	8.3
T ₄	7.95	8.00	245	67	68	46	240.55	11.0
T ₅	7.92	7.95	240	64	67	43	238.20	10.2
T ₆	8.25	8.30	285	80	73	58	280.50	15.7
T ₇	7.65	7.75	205	58	64	35	230.00	8.1
T ₈	8.05	8.15	270	75	70	53	255.70	13.5
T ₉	7.88	7.92	238	63	66	42	232.30	9.7
T ₁₀	8.35	8.40	300	85	75	65	275.80	16.0
T ₁₁	7.55	7.65	195	55	56	35	200.20	7.0
S.Em (±)	0.19	0.14	5.76	2.18	1.57	1.92	8.56	0.35
C.D. at 5%	0.54	0.41	16.70	6.48	4.56	5.76	24.82	1.01

in T₁₀ (75%) and T₆ (73%), which were statistically comparable and superior over all other treatments. Treatments T₂ (71%) and T₈ (70%) were next best. The minimum retention was recorded in T₁₁ (56%). Increased retention under T₆ may be attributed to salicylic acid-mediated enhancement of antioxidant defense mechanisms and reduced ethylene-induced abscission. Under T₁₀, potassium-mediated maintenance of cellular turgor and nitrogen-enhanced metabolic activity contributed to reduced fruit drop. Kazemi (2013) reported that foliar salicylic acid significantly reduced pre-harvest fruit drop through modulation of abscission zone physiology, corroborating present findings. Fruits retained per plant at harvest ranged from 35 to 65 (Table 4). The maximum was recorded in T₁₀ (65), followed by T₆ (58). Treatments T₈ (53) and T₂ (51) were next best. The minimum was recorded in T₇ and T₁₁ (35 each). The improvement in fruit number at harvest under T₁₀ and T₆ reflects the combined effect of higher fruit set, better retention and reduced pre-harvest drop attributable to balanced nutritional and hormonal management throughout fruit development.

Average fruit weight ranged from 200.20 g to 280.50 g (Table 5). The maximum was recorded in T₆ (280.50 g), followed by T₁₀ (275.80 g), which were statistically at par. Treatments T₈ (255.70 g) and T₂ (245.05 g) were next best. The minimum was recorded in T₁₁ (200.20 g). Fruit yield per plant ranged from 7.0 to 16.0 kg/plant (Table 5). The maximum yield was recorded in T₁₀ (16.0 kg/plant), significantly superior to all other treatments including T₆ (15.7 kg/plant). Treatments T₈ (13.5 kg/plant) and T₂ (12.5 kg/plant) were next best. The minimum was recorded in T₁₁ (7.0 kg/plant). The superior fruit weight under T₆ may be attributed to salicylic acid's role in

enhancing source–sink relationships and carbohydrate accumulation in fruits. Salicylic acid at 100 ppm optimizes cell expansion and delays senescence, maintaining active assimilate deposition over a longer period (Ngullieet *al.*, 2014). Zinc and boron further strengthened sink capacity through auxin synthesis and improved phloem transport (Dhurve *et al.*, 2018). Kazemi (2013) reported similar enhancement in pomegranate fruit weight with salicylic acid application. The highest yield of 16.0 kg/plant under T₁₀-representing a 128.6% increase over control-reflects the integrated positive effect on all yield determinants: higher fruit set, superior retention, greater number of fruits at harvest and favorable fruit weight. Foliar potassium nitrate provides simultaneously available nitrogen for metabolic processes and potassium for

Table 4: Effect of foliar application on fruit quality parameters of pomegranate cv. Bhagwa during Hasta bahar (2025–26).

Tr. No.	RS	NRS	TS	βC
T ₁	9.18	1.14	10.32	0.31
T ₂	9.82	1.33	11.15	0.35
T ₃	8.62	0.97	9.59	0.33
T ₄	8.92	1.04	9.96	0.37
T ₅	8.78	1.09	9.87	0.35
T ₆	9.98	1.45	11.43	0.39
T ₇	8.42	0.94	9.36	0.36
T ₈	9.38	1.26	10.64	0.41
T ₉	9.12	1.01	10.13	0.38
T ₁₀	9.68	1.27	10.95	0.44
T ₁₁	8.48	0.91	9.39	0.25
S.Em (±)	0.16	0.02	0.15	0.008
C.D. at 5%	0.46	0.09	0.45	0.02

RS: Reducing Sugar (%); NRS: Non-Reducing Sugar (%); TS: Total Sugar (%); βC: β-Carotene (mg/100 g pulp)

phloem transport and osmotic regulation, creating conditions for maximum fruit load and fruit filling. The synergistic role of zinc in improving photosynthetic efficiency and boron in facilitating carbohydrate transport further amplifies yield output (Chidananda *et al.*, 2020; Gaikwad *et al.*, 2019).

TSS content ranged from 11.1 to 14.9 °Brix (Table 6). The maximum TSS was recorded in T₆ (14.9 °Brix), superior to all treatments and statistically at par with T₂ (14.5 °Brix). T₁₀ (14.2 °Brix) occupied the next position, followed by T₈ (13.2 °Brix). The minimum was recorded in T₁₁ (11.1 °Brix). Higher TSS under T₆ may be attributed to salicylic acid enhancing source-to-sink mobilization and delaying fruit maturity, thereby promoting sugar accumulation. Zinc acted as a cofactor for sugar-metabolizing enzymes, while boron maintained membrane integrity, facilitating efficient sugar translocation (Ngullie *et al.*, 2014; Dhurve *et al.*, 2018). Reducing sugar ranged from 8.48% to 9.98%, non-reducing sugar from 0.91% to 1.45% across treatments (Table 6). For these parameters, T₆ recorded the highest values (9.98%, 1.45% respectively), followed by T₂ and T₁₀ which were statistically comparable. Minimum values for all sugar fractions were recorded in control T₁₁. The increased reducing sugar under T₆ may be due to enhanced invertase activity stimulated by salicylic acid, which promotes hydrolysis of sucrose into glucose and fructose. Higher sucrose (non-reducing sugar) in T₆ indicates improved sucrose phosphate synthase activity promoted by salicylic acid-mediated stress tolerance (Sudha *et al.*, 2018). Zinc as a cofactor for sugar-metabolizing enzymes and boron through membrane stabilization synergistically contributed to enhanced sugar accumulation across all fractions (Dhurve *et al.*, 2018). The superiority of T₂ reflects the role of Cycocel in redirecting assimilates from vegetative to reproductive sinks, enhancing overall sugar accumulation (Gaikwad *et al.*, 2019). Total sugar from 9.36% to 11.43% across treatments (Table 7). For this parameters, T₆ recorded the highest values (11.43%), followed by T₂ and T₁₀ which were statistically comparable. Minimum values for Total sugar fractions were recorded in control T₁₁.

β-Carotene content ranged from 0.25 to 0.44 mg/100 g pulp (Table 7). The highest α-carotene was recorded in T₁₀ (0.44 mg/100 g pulp), statistically superior to all other treatments. T₈ (0.41 mg/100 g pulp) occupied the next position, followed by T₆ (0.39 mg/100 g pulp). The minimum was recorded in T₁₁ (0.25 mg/100 g pulp). The highest β-carotene under T₁₀ may be attributed to the role of potassium in facilitating chloroplast-to-chromoplast transition during ripening, which is the primary site of

carotenoid biosynthesis. Potassium enhances sugar transport and energy supply for carotenoid biosynthetic pathways, while zinc, as a cofactor for phytoene synthase and related enzymes, promotes carotenoid accumulation. The nitrate component of potassium nitrate provides nitrogen for biosynthesis of carotenoid pathway proteins. Korkmaz *et al.*, (2016) and Hassan *et al.*, (2024) reported enhanced β-carotene accumulation in pomegranate fruits under potassium-enriched nutritional regimes, supporting the present results.

Conclusion

Foliar application of growth regulators, chemicals and micronutrients significantly improved flowering, fruit yield and fruit quality of pomegranate cv. Bhagwa during Hasta bahar. Among the treatments, T₁₀ (Potassium nitrate 2% + 0.2% ZnSO₄ + 0.2% boric acid) was the most effective for enhancing fruit retention, yield and α-carotene content, while T₆ (Salicylic acid 100 ppm + 0.2% ZnSO₄ + 0.2% boric acid) proved superior for improving fruit quality by recording the highest fruit weight, TSS and total sugars. Therefore, T₁₀ may be recommended for maximizing yield, whereas T₆ is recommended for producing superior-quality fruits under Hasta bahar conditions.

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Conflict of Interest: The authors declare no conflict of interest.

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