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EFFECT OF PLANT GROWTH REGULATORS AND NUTRIENTS ON FLOWERING BEHAVIOUR OF POMEGRANATE (*Punica granatum* L.) cv. BHAGWA UNDER HASTA BAHAR

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ABSTRACT

This research assessed the effects of nutrients and plant growth regulators on the flowering behaviour of pomegranate (*Punica granatum* L.) cv. Bhagwa under Hasta Bahar conditions. The experiment was conducted during 2025–2026 in a four-year-old orchard at Hire Samshi, Bagalkot, using a randomized block design with ten treatments and three replications. The treatments comprised foliar applications of naphthaleneacetic acid (NAA), cycocel (CCC), salicylic acid, potassium nitrate and nitrobenzene, alone or in combination with zinc sulphate (0.2%) and boric acid (0.2%), along with a water-spray control. Flowering behaviour was evaluated based on male and hermaphrodite flowers at 45, 60 and 75 days after defoliation (DAD). Significant differences were observed among treatments for all flower types. The control recorded the highest number of male flowers (47.11, 56.21 and 65.15), whereas T_3 (CCC 2000 ppm + $ZnSO_4$ 0.2% + boric acid 0.2%) recorded the lowest (31.79, 38.52 and 46.51) at 45, 60 and 75 DAD, respectively. Conversely, T_3 produced the highest number of hermaphrodite flowers (31.70, 55.94 and 98.81), while the control recorded the lowest (23.30, 44.92 and 81.85). The total number of flowers, including male, hermaphrodite and intermediate flowers was recorded in T_7.

Key words : Pomegranate, Bhagwa, Hasta Bahar, Hermaphrodite flowers.

Introduction

Pomegranate (*Punica granatum* L.) is an important fruit crop of considerable commercial, nutritional and therapeutic value. Pomegranate production in India has expanded due to increasing demand in domestic and international markets (Anonymous, 2019). India is one of the leading producers of pomegranate. At the same time 'Bhagwa' has become one of the most commercially important cultivars owing to its attractive red fruit, deep-red arils, high juice content and good eating quality (APEDA, 2024; Singh *et al*., 2019).

Pomegranate can flower almost year-round under tropical and semi-arid conditions. However, continuous flowering may result in depletion or imbalance of nutrient and carbohydrate reserves among successive flowering flushes, leading to poor fruit set, reduced fruit size and variable fruit quality (Kumar *et al*., 2020). Therefore, regulation of flowering into a synchronised flush is important for obtaining uniform fruit maturity, improved productivity and better fruit quality. The crop is commonly regulated through three bahars, namely Ambe Bahar, Mrig Bahar and Hasta Bahar (Durgude *et al*., 2019). Among these, Hasta Bahar, generally occurring during September–October, is adopted to obtain synchronised flowering and uniform fruit maturity.

Flowering behaviour in pomegranate is influenced by environmental factors such as temperature, rainfall and seasonal variations (Pareek and Sharma, 1993). The crop produces both staminate and hermaphrodite flowers, with hermaphrodite flowers being primarily responsible for fruit production (Chaudhari and Desai, 1993). Hence, regulation of floral sex expression towards a greater

proportion of productive hermaphrodite flowers is important for improving fruit set and productivity. Flower regulation in pomegranate can be influenced through plant growth regulators, nutrient management, moisture regulation and other crop management practices.

Foliar application of nutrients provides an effective means of supplying nutrients during critical stages of crop development and has been reported to improve growth, yield and fruit quality in pomegranate (Gaikwad *et al*., 2019). Zinc and boron are particularly important for reproductive development, and foliar application of these nutrients has been reported to improve reproductive and yield-related parameters of pomegranate under Hasta Bahar conditions (Dhurve *et al*., 2018). Plant growth regulators such as gibberellic acid (GA_3), naphthalene acetic acid (NAA), cycocel and other growth-modifying compounds can influence flowering, fruit set and assimilate partitioning.

Integrated application of plant growth regulators and mineral nutrients at critical phenological stages has the potential to improve flowering, fruit set, yield and fruit quality. However, systematic information regarding their combined application for flowering regulation in pomegranate, particularly under Hasta Bahar conditions, remains limited and inconclusive (Gaikwad *et al*., 2019). Therefore, the present investigation, "Effect of Plant Growth Regulators and Nutrients on Flowering Behaviour of Pomegranate (*Punica granatum* L.) cv. Bhagwa under Hasta Bahar", was undertaken.

Materials and Methods

The experiment was conducted during 2025–2026 in a farmer's field at Hire Samshi, Bagalkot, Karnataka, India, using a four-year-old pomegranate (*Punica granatum* L.) cv. Bhagwa orchard maintained under Hasta Bahar conditions. The orchard was planted at a spacing of 4 m × 3 m. The experiment was laid out in a randomized block design (RBD) with ten treatments and three replications. Each treatment consisted of three plants in each replication, giving a total of 90 experimental plants. All the plants were maintained under uniform cultural practices and supplied with the recommended dose of fertilizers, *i.e*., 400:200:200 g plant^{-1} N:P_2O_5 :K_2O, as recommended by the University of Horticultural Sciences, Bagalkot.

The treatments included foliar application of different plant growth regulators and mineral nutrients, namely naphthalene acetic acid (NAA), cycocel (CCC), salicylic acid, potassium nitrate, nitrobenzene, zinc sulphate and boric acid. The treatment combinations consisted of NAA at 40 ppm (T_1); cycocel at 1500 ppm + zinc sulphate at 0.2% + boric acid at 0.2% (T_2); cycocel at 2000 ppm + zinc sulphate at 0.2% + boric acid at 0.2% (T_3); salicylic acid at 100 ppm + zinc sulphate at 0.2% + boric acid at 0.2% (T_4); salicylic acid at 200 ppm + zinc sulphate at 0.2% + boric acid at 0.2% (T_5); potassium nitrate at 2% + zinc sulphate at 0.2% + boric acid at 0.2% (T_6); potassium nitrate at 3% + zinc sulphate at 0.2% + boric acid at 0.2% (T_7); nitrobenzene at 0.1% + zinc sulphate at 0.2% + boric acid at 0.2% (T_8); nitrobenzene at 0.2% + zinc sulphate at 0.2% + boric acid at 0.2% (T_9) and water spray as the untreated control (T_{10}).

The foliar treatments were applied at the specified crop growth stages according to the respective treatment schedule. NAA was applied four times at weekly intervals, starting one month before defoliation. The other treatment combinations were applied through three foliar sprays, with the first spray given one month before bud break, the second at full bloom and the third one month after full bloom. Zinc sulphate and boric acid were applied along with the respective plant growth regulator or nutrient treatment as specified in the treatment schedule. The control plants received water spray at the corresponding stages.

The required working solutions were prepared freshly before each application. Cycocel solutions at 1500 and 2000 ppm were prepared by dissolving the required quantity of the commercial formulation in water to obtain the desired concentrations. Salicylic acid at 100 and 200 ppm was prepared by dissolving 1 and 2 g, respectively, in 10 L of water. Potassium nitrate solutions at 2 and 3% were prepared by dissolving 200 and 300 g, respectively, in 10 L of water. For preparing 0.2% solutions of zinc sulphate and boric acid, 20 g of each chemical was dissolved separately in 10 L of water. NAA at 40 ppm was prepared from the commercial formulation based on its active ingredient concentration. Nitrobenzene solutions at 0.1 and 0.2% were prepared using the commercial formulation at the required concentrations. The prepared solutions were applied as foliar sprays using a knapsack sprayer to ensure uniform coverage of the plants.

Flowering behaviour was assessed by recording the number of male, hermaphrodite and total flowers on selected shoots of each experimental plant. Representative shoots were selected uniformly from the experimental plants and tagged for recording observations. Male (staminate) flowers, identified by their bell-shaped structure, rudimentary ovary and functional stamens, were counted manually on the selected shoots. Hermaphrodite (bisexual) flowers, identified by their well-

developed ovary along with functional stamens and pistil, were counted in a similar manner. Observations on male and hermaphrodite flowers were recorded at 45, 60 and 75 days after defoliation (DAD) and expressed as the number of flowers per shoot. The total number of flowers was calculated by adding the number of male and hermaphrodite flowers recorded on the selected shoots and expressed as total flowers per shoot.

The observations recorded for the different flowering parameters were tabulated treatment-wise and subjected to analysis of variance appropriate for a randomized block design. The significance of differences among the treatment means was tested using the F-test at the 5% probability level following the procedure described by Cochran and Cox (1957). When the F-test showed significant differences among treatments, the critical difference (CD) at the 5% level of significance was calculated to compare the treatment means. The standard error of the mean (SEm±) was also calculated to indicate the precision of the treatment means.

Results

Total number of male flowers

The number of male flowers was recorded at 45, 60, and 75 days after defoliation to evaluate the effects of foliar applications of plant growth regulators and nutrients on flowering behaviour in pomegranate. The treatment-wise mean values are presented in Table 1.

Total number of male flowers at 45 days after defoliation

The data presented in Table 1 revealed significant differences in the number of male flowers among the treatments at 45 days after defoliation. The highest number of male flowers (47.11) was recorded in the untreated control (T_{10}), which was statistically on par with T_6 (46.78) and T_7 (45.98). These were followed by T_4 (42.48) and T_5 (41.62). The lowest number of male flowers (31.79) was recorded in T_3 (CCC @ 2000 ppm + $ZnSO_4$ @ 0.2% + boric acid @ 0.2%).

Total number of male flowers at 60 days after defoliation

The data presented in Table 1 revealed that the number of male flowers differed significantly among the treatments at 60 days after defoliation. A trend similar to that observed at 45 DAD was recorded at this stage. The highest number of male flowers (56.21) was recorded in the untreated control (T_{10}), which was statistically on par with T_6 (54.21) and T_7 (53.97). These treatments were followed by T_4 (47.81) and T_5 (47.26). The lowest number of male flowers (38.52) was recorded in T_3.

Total number of male flowers at 75 days after defoliation

The data presented in Table 1 revealed significant differences in the number of male flowers among the treatments at 75 days after defoliation. The highest number of male flowers (65.15) was recorded in the untreated control (T_{10}), which was statistically on par with T_7 (64.86) and T_6 (64.32). These treatments were followed by T_4 (57.98), T_5 (57.50), T_1 (53.12), T_8 (52.24), T_2 (50.22) and T_9 (47.26). The lowest number of male flowers (46.51) was recorded in T_3 (CCC @ 2000 ppm + $ZnSO_4$ @ 0.2% + boric acid @ 0.2%).

Total number of hermaphrodite flowers

The data pertaining to the number of hermaphrodite flowers as influenced by the foliar application of plant growth regulators and nutrients at 45, 60 and 75 days after defoliation are presented in Table 2.

Total number of hermaphrodite flowers at 45 days after defoliation

The data presented in Table 2 revealed significant differences in the number of hermaphrodite flowers among the treatments at 45 days after defoliation. The highest number of hermaphrodite flowers (31.70) was recorded in T_3 (CCC @ 2000 ppm + $ZnSO_4$ @ 0.2% + boric acid @ 0.2%), which was statistically on par with T_2 (31.14) and T_9 (30.64). The lowest number of hermaphrodite flowers (23.30) was recorded in the untreated control (T_{10}).

Total number of hermaphrodite flowers at 60 days after defoliation

The data presented in Table 2 revealed significant differences in the number of hermaphrodite flowers among the treatments at 60 days after defoliation. The highest number of hermaphrodite flowers (55.94) was recorded in T_3 (CCC @ 2000 ppm + $ZnSO_4$ @ 0.2% + boric acid @ 0.2%), which was statistically on par with T_2 (54.95), T_8 (53.30) and T_9 (54.08). The lowest number of hermaphrodite flowers (44.92) was recorded in the untreated control (T_{10}).

Total number of hermaphrodite flowers at 75 days after defoliation

A further increase in the number of hermaphrodite flowers was recorded at 75 DAD. The maximum number of hermaphrodite flowers (98.81) was obtained in T_3, which was statistically on par with T_2 (97.06) and T_9 (95.53), whereas the minimum number of hermaphrodite flowers (81.85) was observed in the control (T_{10}).

Total number of flowers

The data pertaining to the number of total flowers as

Table 1 : Number of male flowers as influenced by foliar application of PGRs and nutrients on pomegranate during hasta bahar conditions.

Male flowers			
Treatment	**45 DAD**	**60 DAD**	**75 DAD**
T_1	37.80	46.51	53.12
T_2	37.50	44.01	50.22
T_3	31.79	38.52	46.51
T_4	42.48	47.81	57.98
T_5	41.62	47.26	57.50
T_6	46.78	54.21	64.32
T_7	45.98	53.97	64.86
T_8	39.12	45.52	52.24
T_9	34.83	42.76	47.26
T_{10}	47.11	56.21	65.15
S.EM±	**1.07**	**0.82**	**0.75**
CD at 5%	**3.18**	**2.43**	**2.23**

Table 2 : Number of hermaphrodite flowers as influenced by foliar application of PGRs and nutrients on pomegranate during hasta bahar conditions

Hermaphrodite flowers			
Treatment	**45 DAD**	**60 DAD**	**75 DAD**
T_1	29.73	52.47	92.70
T_2	31.14	54.95	97.06
T_3	31.70	55.94	98.81
T_4	28.82	50.85	89.84
T_5	29.28	51.68	91.29
T_6	26.94	47.54	83.99
T_7	27.57	48.65	85.94
T_8	30.20	53.30	94.15
T_9	30.64	54.08	95.53
T_{10}	23.30	44.92	81.85
S.EM±	**0.38**	**0.97**	**1.46**
CD at 5%	**1.13**	**2.90**	**4.34**

influenced by the foliar application of plant growth regulators and nutrients at 45, 60 and 75 days after defoliation are presented in Table 3.

Total number of flowers at 45 days after defoliation

The data presented in Table 3 revealed significant differences in the total number of flowers among the treatments at 45 days after defoliation. The highest total number of flowers (82.66) was recorded in T_7 (Potassium nitrate @ 3% + $ZnSO_4$ @ 0.2% + boric acid @ 0.2%), which was statistically on par with T_6 (82.23) and the lowest total number of flowers (67.12) was recorded in the control (T_{10}).

Total number of flowers at 60 days after defoliation

The data on total number of flowers at 60 DAD varied

Table 3 : Total number of flowers as influenced by foliar application of PGRs and nutrients on pomegranate during hasta bahar conditions.

Total number of flowers			
Treatment	**45 DAD**	**60 DAD**	**75 DAD**
T_1	74.38	108.77	161.15
T_2	74.35	106.57	157.95
T_3	68.29	100.35	154.16
T_4	77.60	108.37	161.08
T_5	77.97	109.08	163.09
T_6	82.23	114.64	166.10
T_7	82.66	116.06	168.67
T_8	76.38	108.34	160.93
T_9	71.10	103.88	155.31
T_{10}	67.12	98.80	141.80
S.EM±	**1.09**	**1.78**	**2.68**
CD at 5%	**3.24**	**5.29**	**7.95**

significantly amongst all the treatments. The highest total flowers were recorded in T_7 (116.06), which was statistically at par with T_6 (114.64) and on a contrary the least flowers were obtained in the T_{10} (98.80).

Total number of flowers at 75 days after defoliation

The data presented in Table 3 revealed significant differences in the total number of flowers. The highest total flowers were recorded in T_7 (168.67), which was statistically at par with T_4 (114.64) and on the contrary, the least flowers were obtained in T_{10} (98.80).

Discussion

Total number of male flowers

The reduction in male flower production under CCC-based treatments may be attributed to the anti-gibberellin action of cycocel, which suppresses excessive vegetative growth, regulates hormonal balance and promotes the allocation of photosynthates towards reproductive sinks. This favours the differentiation of hermaphrodite over staminate flowers, thereby improving reproductive efficiency. The effect of cycocel may have been further enhanced by zinc and boron, which contribute to enzyme activation, auxin biosynthesis, carbohydrate translocation, pollen development and reproductive organ differentiation. Similar findings were reported by Hussain *et al.* (2021), who observed that foliar application of cycocel reduced male flower production while increasing hermaphrodite flowers in pomegranate cv. Bhagwa.

In contrast, the control (T_{10}) consistently recorded the highest number of male flowers, indicating the absence of treatments to regulate floral sex expression. This resulted in a greater proportion of staminate flowers and

lower reproductive potential. Similar improvements in flowering behaviour and reproductive efficiency following zinc and boron application were reported by Kant *et al*. (2020), while Raigond *et al*. (2024) observed that combined application of plant growth regulators favourably altered the hermaphrodite-to-male flower ratio in pomegranate.

The marked reduction in male flowers under T_3, accompanied by increased hermaphrodite flower production, indicates that CCC combined with zinc sulphate and boric acid effectively favoured productive floral differentiation. This shift in floral sex expression is important for improving fruit set, yield potential and overall productivity in pomegranate. The response of hermaphrodite flower production is discussed in the following section.

Total number of hermaphrodite flowers

The data presented in Table 4 revealed that foliar application of plant growth regulators and nutrients significantly influenced hermaphrodite flower production at 45, 60 and 75 days after defoliation (DAD). T_3 (CCC @ 2000 ppm + $ZnSO_4$ @ 0.2% + boric acid @ 0.2%) consistently recorded the highest number of hermaphrodite flowers (31.70, 55.94 and 98.81), whereas the control (T_{10}) recorded the lowest values (23.30, 44.92 and 81.85), respectively. This indicates that the combined application of CCC, zinc sulphate and boric acid promoted differentiation towards hermaphrodite flowers.

The superior performance of T_3 may be attributed to the anti-gibberellin action of CCC, which restricts excessive vegetative growth and favours carbohydrate accumulation in developing floral buds. Enhanced carbohydrate availability and favourable hormonal balance promote bisexual flower differentiation over staminate flowers. Zinc and boron further complement this effect through their roles in enzyme activation, auxin biosynthesis, carbohydrate translocation, pollen development and reproductive organ differentiation. Similar findings were reported by Patil *et al*. (2024), who observed increased hermaphrodite flower production following foliar application of plant growth regulators combined with zinc sulphate and boric acid in pomegranate.

In contrast, the control (T_{10}) produced the lowest number of hermaphrodite flowers, indicating limited floral differentiation and reproductive development in the absence of growth regulators and micronutrients. Similar beneficial effects of zinc and boron on flowering and reproductive efficiency in pomegranate were reported by Guleria *et al*. (2025). Kumar *et al*. (2025) also reported that the integration of suitable plant growth regulators with balanced nutrient management improved floral differentiation and reproductive performance in pomegranate.

Total number of flowers

The data presented in Table 5 revealed that foliar application of plant growth regulators and nutrients significantly influenced the total number of flowers at 45, 60 and 75 days after defoliation (DAD). T_7 (KNO_3 @ 3% + $ZnSO_4$ @ 0.2% + boric acid @ 0.2%) consistently recorded the highest total number of flowers (82.66, 116.06 and 168.67), whereas the control (T_{10}) recorded the lowest values (67.12, 98.80 and 141.80), respectively. This indicates that the combined application of potassium nitrate, zinc sulphate and boric acid enhanced flowering in pomegranate.

The superior flowering response under T_7 may be attributed to potassium nitrate enhancing nitrogen assimilation, photosynthetic efficiency and assimilate translocation to developing floral buds, thereby promoting flower initiation and development. Zinc and boron further supported these processes through their roles in enzyme activation, auxin biosynthesis, carbohydrate metabolism, pollen development and reproductive growth. Similar improvements in flowering, fruit set and reproductive performance following potassium-based foliar treatments in pomegranate were reported by Raigond *et al*. (2024).

In contrast, the control (T_{10}) recorded the lowest flower production, indicating limited floral induction and reproductive development in the absence of foliar nutrients and growth regulators.

Overall, the treatments enhanced flowering through different physiological mechanisms. The cycoceal combined with zinc sulphate and boric acid favoured hermaphrodite flower formation and reduced male flowers, thereby improving floral sex expression, whereas KNO_3 with zinc sulphate and boric acid promoted greater flower production through enhanced photosynthetic activity and assimilate availability. These responses collectively created favourable conditions for improved fruit set, yield and productivity in pomegranate.

Conclusion

The present investigation demonstrated that foliar application of plant growth regulators and nutrients influenced the flowering behaviour of pomegranate cv. Bhagwa under Hasta Bahar conditions. Among the treatments, T_3 (CCC 2000 ppm + 0.2% $ZnSO_4$ + 0.2% boric acid) consistently recorded the lowest number of male flowers and the highest number of hermaphrodite

flowers at 45, 60 and 75 days after defoliation. The treatment therefore showed better productive floral development compared with the other treatments and control. Overall, the combined application of CCC, zinc sulphate and boric acid showed potential for improving the flowering behaviour of pomegranate cv. Bhagwa under Hasta Bahar conditions.

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