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Foliar Application of Chelated Micronutrients, Gibberellic Acid and Biofertilisers Improves Vegetative Growth, Fruit Retention and Yield of Pomegranate (*Punica granatum* L.) cv. Bhagwa

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

Pomegranate orchards in the Marathwada region of Maharashtra frequently exhibit suboptimal canopy development and heavy fruitlet abscission, both of which limit marketable yield. A two-year field experiment was conducted during the mrig bahar seasons of 2018–19 and 2019–20 at Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, on five-year-old Bhagwa trees to quantify the responses of vegetative growth, flowering behaviour, fruit retention and yield to eleven foliar treatments comprising chelated micronutrients (3.0 and 4.0 g L^{-1}), gibberellic acid (75 and 100 ppm), the biofertiliser consortium Biomix (0.3 and 0.4%), their combinations and an unsprayed control, each applied three times, at 45, 90 and 135 days after flowering. The experiment was laid out in a Factorial Randomised Block Design with two propagation methods (air-layered and tissue-cultured plants) and two replications. Pooled over seasons, the three-way combination of chelated micronutrients at 3.0 g L^{-1} + GA_3 at 75 ppm + Biomix at 0.3% (N_8) produced the tallest trees (255.53 cm at 90 DAF against 187.57 cm in the control), the greatest number of branches per plant (16.58 against 11.51), the most leaves per branch (1097.80 against 806.02) and the widest stem girth (17.23 cm against 13.04 cm). The same treatment advanced flowering, lowered fruit drop and recorded the highest yield of 18.27 kg per plant and 13.52 t ha^{-1}, exceeding the control by 47.3 per cent, while the control gave only 12.40 kg per plant and 9.18 t ha^{-1}. Fruit set and the number of fruits retained at harvest responded differently, with the highest values recorded under GA_3 at 100 ppm (81.52 and 70.94 per plant, respectively). Three sprays of chelated micronutrients at 3.0 g L^{-1} + GA_3 at 75 ppm + Biomix at 0.3% are therefore recommended for improving the productivity of Bhagwa pomegranate under Marathwada conditions.

Keywords: Bhagwa pomegranate; chelated micronutrients; gibberellic acid; Biomix; foliar spraying; vegetative growth; flowering behaviour; fruit set; fruit retention; fruit yield.

1. Introduction

Pomegranate (*Punica granatum* L.) has become one of the most remunerative fruit crops of the semi-arid tropics, and India is now the leading producer, with Maharashtra alone accounting for the largest share of the national area under the crop (National Horticulture Board, 2020; FAO, 2019). Cultivar Bhagwa dominates commercial plantings because of its vigorous growth habit and its acceptance in both domestic and export markets (Kahramanoğlu, 2019; Melgarejo-Sánchez *et al*., 2015).

Under the *mrig bahar* cropping pattern of Marathwada, the crop is grown during a period of high evaporative demand, and orchards commonly show restricted shoot extension, sparse canopy renewal and heavy abscission of fruitlets between fruit set and harvest. Since the canopy is the source and the developing fruit the sink, any intervention that simultaneously enlarges the photosynthetic surface and improves the retention of set fruit has a direct effect on yield. Foliar sprays are especially suited to this purpose in calcareous, high-pH soils, where soil-applied micronutrients are rapidly rendered unavailable (Marschner, 2012; Cakmak *et al.*, 2023). Recent field evidence from pomegranate cv. Kandhari indicates that combined foliar application of zinc and boron can improve canopy growth, fruit set and yield (Guleria *et al*., 2025). Foliar zinc- and boron-based nanoparticle treatments have also been associated with vegetative and fruit-retention responses in cv. Wonderful, although these formulations differ from the chelated micronutrients examined here (Abd El-wahed *et al*., 2024).

Zinc, iron, manganese and boron participate directly in chlorophyll formation, enzyme activation, auxin metabolism, pollen viability and the translocation of assimilates, and their foliar supply has improved growth and yield in pomegranate and other fruit crops (Yadav *et al.*, 2022; Meena *et al*., 2023; Bhoyar and Ramdevputra, 2016). Gibberellic acid promotes cell elongation and division, enhances the sink strength of developing fruit and reduces abscission, and has raised yield attributes in pomegranate in several regions (Thakur and Sharma, 2020; Jhade *et al.*, 2020). Liquid biofertiliser consortia improve nutrient acquisition, rhizosphere microbial activity and growth in pomegranate and guava (Mir *& Sharma*, 2012; Singh *et al.*, 2020; Rani *et al.*, 2021). These three classes of input act on different, potentially complementary steps, yet they are usually evaluated separately, and information on their combined foliar use under a defined spray programme in Bhagwa pomegranate remains limited.

In pomegranate plantlets, foliar GA_3 has been reported to promote shoot elongation and leaf development, although responses in plantlets may not directly reflect those of established orchard trees (Tang *et al*., 2025). Research on microbial inoculants in pomegranate has likewise shown altered physiological responses under salinity stress, but these inputs and growing conditions differ from the present foliar Biomix treatment (Ziatabar Ahmadi *et al*., 2024). An integrated nutrient-management study of Bhagwa under ambe bahar conditions also reported improvements in growth and flowering with a programme that included a bio-NPK consortium and a micronutrient foliar spray (Ranjith & Rajeswari, 2026).

However, evidence remains limited on the combined effects of these three foliar inputs, applied on a common schedule, on canopy growth, reproductive development, fruit retention and yield in Bhagwa under Marathwada conditions.

The present study was therefore undertaken to quantify, over two consecutive *mrig bahar* seasons, the effect of chelated micronutrients, gibberellic acid and a biofertiliser consortium, applied singly and in combination as three foliar sprays at 45, 90 and 135 days after flowering, on the vegetative growth, flowering behaviour, fruit retention and yield of pomegranate cv. Bhagwa.

2. Materials and Methods

2.1 Experimental Site and Plant Material

The investigation was carried out during the *mrig bahar* cropping seasons of 2018–19 and 2019–20 at the Department of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India. Healthy, uniformly grown, five-year-

old pomegranate trees of the cultivar Bhagwa, planted at a spacing of 4.0 m × 3.0 m (833 trees ha^{-1}), formed the experimental material. Two sets of trees of identical age and planting date were used: one raised from air layers and the other from tissue-cultured plantlets, so that the propagation method could be treated as an experimental factor under a common orchard, soil and management environment. All trees received the recommended package of practices for irrigation, pruning, *bahar* regulation and plant protection uniformly throughout both seasons, so that the treatment differences reported here are attributable to the imposed foliar treatments and to the propagation method.

2.2 Treatments and Experimental Design

The experiment was laid out in a Factorial Randomised Block Design (FRBD) with two factors and two replications, with four plants maintained per treatment combination. Factor P comprised two propagation methods, namely P_1 (air-layered plants) and P_2 (tissue-cultured plants). Factor N comprised eleven foliar nutrient and growth-regulator treatments, including chelated micronutrients and gibberellic acid (GA_3) at two concentrations each, the liquid biofertiliser consortium Biomix at two concentrations, four combinations of these inputs and an unsprayed control, giving 22 treatment combinations in all. The treatments are listed in Table 1.

Table 1. Foliar treatments imposed on air-layered and tissue-cultured Bhagwa pomegranate trees

Notation	Foliar treatment (applied at 45, 90 and 135 DAF)
N_1	Chelated micronutrients @ 3.0 g L^{-1}
N_2	Chelated micronutrients @ 4.0 g L^{-1}
N_3	GA_3 @ 75 ppm
N_4	GA_3 @ 100 ppm
N_5	Biomix @ 0.3%
N_6	Biomix @ 0.4%
N_7	Chelated micronutrients @ 3.0 g L^{-1} + Biomix @ 0.3%
N_8	Chelated micronutrients @ 3.0 g L^{-1} + GA_3 @ 75 ppm + Biomix @ 0.3%
N_9	Chelated micronutrients @ 3.0 g L^{-1} + GA_3 @ 75 ppm
N_{10}	GA_3 @ 75 ppm + Biomix @ 0.3%
N_{11}	Control (water spray)

Each treatment was applied as three foliar sprays at 45, 90 and 135 days after flowering (DAF), using a knapsack sprayer during the cooler part of the day and spraying to run-off so that the entire canopy was uniformly wetted. Control trees received an equivalent volume of water at the same three dates. Because a single spray schedule was used for every treatment, the design permits comparisons among treatments and concentrations within that schedule, but it does not permit any comparison among alternative spray dates or spray numbers.

2.3 Observations Recorded

Vegetative growth was recorded on four tagged shoots and on the whole tree at 30, 60 and 90 DAF and comprised plant height, number of primary and secondary branches per plant, number of leaves per branch, canopy spread in the north–south and east–west directions and stem girth measured at 15 cm above the ground level. Reproductive behaviour was assessed as days taken to flowering initiation, days taken to 50 per cent flowering, total number of flowers per plant, number of male flowers per plant and the sex ratio. Yield attributes comprised the number of fruits set per plant, the number of fruits dropped per plant, the percentage of fruit drop and the number of fruits retained per plant at harvest. Physical yield components were recorded on ten randomly selected fruits per treatment at harvest and comprised average fruit weight, fruit length, fruit diameter, the weight of 100 arils and the number of arils per fruit. Yield was recorded as yield per plant and computed on an area basis as yield per hectare from the population of 833 trees ha^{-1}. Percentage data were subjected to angular transformation before analysis, and the transformed values are given in parentheses in the relevant table.

2.4 Statistical Analysis

Data were subjected to analysis of variance appropriate to a Factorial Randomised Block Design following Panse and Sukhatme (1985). Standard errors of the mean (S.E. ±) and critical differences at the 5 per cent level of significance (C.D. at 5%) were computed for the propagation-method effect, the nutrient-treatment effect and their interaction. Differences between two means were regarded as significant only where they equalled or exceeded the relevant critical difference; where the F-test was non-significant this is indicated as NS in the tables and no interpretation of ranking is offered. Means of the two seasons were pooled after confirming the consistency of treatment behaviour across years, and both the individual-year and pooled means are reported.

3. Results and Discussion

3.1 Vegetative Growth and Canopy Development

Foliar treatments markedly modified vegetative growth throughout the 90-day observation period (Tables 2–4; Fig. 1 and 2). The three-component treatment N_8 [chelated micronutrients at 3.0 g L^{-1} + GA_3 at 75 ppm + Biomix at 0.3%] consistently produced the greatest plant height, branch number, leaves per branch and stem girth. Pooled plant height under N_8 increased from 199.31 cm at 30

DAF to 255.53 cm at 90 DAF, compared with 143.65 and 187.57 cm, respectively, under the control. The same treatment increased branches per plant, leaves per branch and stem girth by 44.0, 36.2 and 32.1%, respectively, relative to the control. Canopy spread showed the same general advantage of N_8, although the statistical response varied among observation dates and directions (Table 4). These results indicate that the treatment did not merely stimulate a single growth attribute but promoted coordinated shoot and canopy development. Propagation method also contributed significantly: air-layered plants were taller at all three observation dates and had more branches, leaves and stem girth than tissue-cultured plants, indicating that the established physiological status or root–shoot balance of air-layered plants may have supported more rapid canopy establishment under the common orchard conditions. Because the propagation effect was observed independently of the imposed foliar programme, it should be regarded as an additional source of variation rather than as evidence that the foliar treatments acted differently in the two propagation systems.

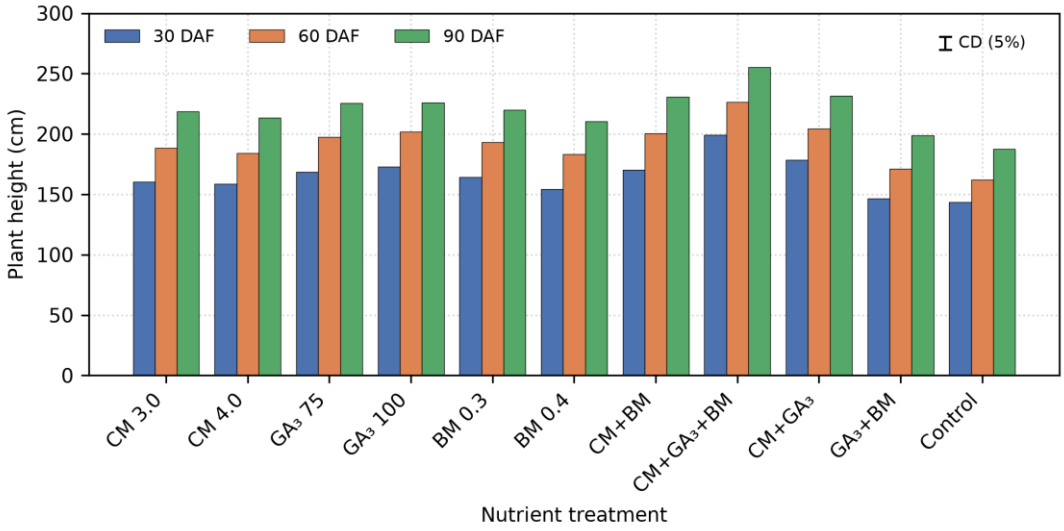


Fig. 1. Plant height of Bhagwa pomegranate at 30, 60 and 90 days after flowering as influenced by foliar treatments (pooled means of 2018–19 and 2019–20). CM = chelated micronutrients, GA_3 = gibberellic acid, BM = Biomix

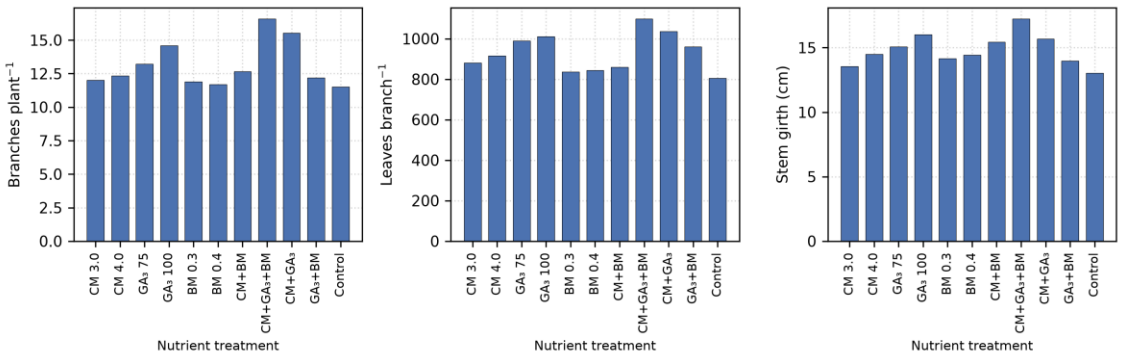


Fig. 2. Number of branches per plant, number of leaves per branch and stem girth of Bhagwa pomegranate as influenced by foliar treatments (pooled means)

3.2 Flowering Behaviour and Reproductive Development

The foliar treatments also altered the timing and magnitude of flowering (Table 5). N_8 reduced the time taken to initiate flowering to 41.35 days compared with 49.40 days in the control and reached 50% flowering in 23.45 days compared with 29.08 days in the control. It also produced the greatest total number of flowers (195.43 plant^{-1}) and male flowers (106.62 plant^{-1}), whereas the control produced 175.81 and 85.73 plant^{-1}, respectively. These results suggest that the integrated spray programme influenced both vegetative–reproductive transition and the development of reproductive structures. However, the treatment effect on sex ratio was not aligned with the highest flower number: the narrowest sex ratio was observed with Biomix at 0.3% (N_5), indicating that the components of the spray mixture can influence different aspects of reproductive development independently.

3.3 Fruit Set, Fruit Retention and Yield

Fruit set and fruit retention responded differently from vegetative growth and flowering, demonstrating that the treatment producing the largest canopy was not necessarily the treatment producing the greatest number of fruits (Table 6; Fig. 3). GA_3 at 100 ppm (N_4)

gave the highest fruit set (81.52 plant^{-1}) and the highest number of fruits retained at harvest (70.94 plant^{-1}). In contrast, the percentage of fruit drop was lowest under N_8 (3.71%) and highest in the control (4.96%). Thus, the advantage of N_8 was expressed more strongly through improved retention and subsequent fruit growth than through maximisation of the initial number of fruits set. Air-layered plants also showed significantly greater fruit set and fruit retention than tissue-cultured plants, which is consistent with their stronger vegetative growth and larger canopy. This distinction is important because reproductive output in pomegranate depends on the balance between fruit number and the capacity of the tree to support developing sinks.

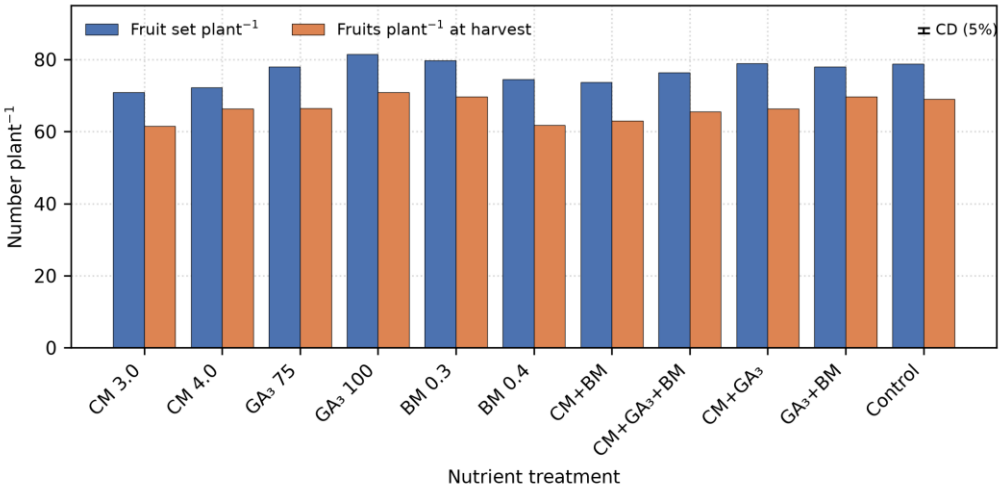


Fig. 3. Fruit set per plant and number of fruits retained per plant at harvest in Bhagwa pomegranate as influenced by foliar treatments (pooled means)

The yield response provides the clearest evidence of the agronomic value of the integrated treatment (Table 7; Fig. 4). N_8 produced 18.27 kg plant^{-1} and 13.52 t ha^{-1}, representing a 47.3% increase over the control (12.40 kg plant^{-1} and 9.18 t ha^{-1}). Its yield was also significantly greater than those of N_7, N_9 and N_{10}, indicating that adding the third component to the two-component combinations produced an additional response that was large enough to exceed the critical difference. Air-layered plants also produced significantly greater yield (15.37 kg plant^{-1}; 11.37 t ha^{-1}) than tissue-cultured plants (14.66 kg plant^{-1}; 10.85 t ha^{-1}). The yield ranking therefore cannot be explained by fruit number alone: N_4 produced the greatest fruit set and retention, whereas N_8 produced the greatest yield. The most plausible interpretation from the present dataset is that the larger canopy, improved fruit retention and superior fruit physical attributes under N_8 together increased the amount of assimilate available to individual developing fruits. Similar evidence that foliar nutrient and growth-regulator programmes can improve pomegranate productivity has been synthesised by Moradinezhad and Ranjbar (2024), while recent field work has also shown that combined foliar nutrient programmes can enhance vegetative growth and yield relative to untreated pomegranate trees (Ahmed *et al*., 2024).

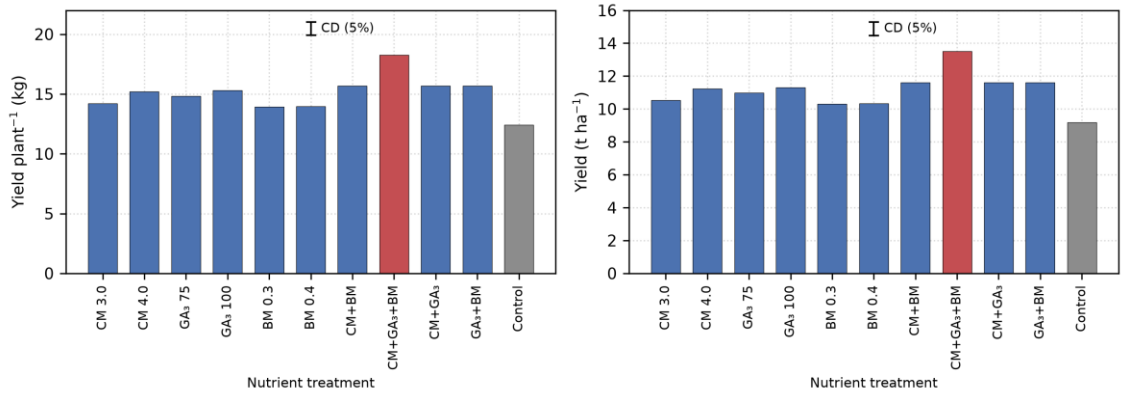


Fig. 4. Yield per plant and yield per hectare of Bhagwa pomegranate as influenced by foliar treatments (pooled means). The vertical bar denotes the critical difference at the 5 per cent level

3.4 Physical Yield Components and Integrated Treatment Response

The physical characteristics of the harvested fruits further indicate the advantage of N_8 (Fig. 5). Under N_8, mean fruit weight reached 282.40 g compared with 179.71 g in the control, while fruit length increased from 6.74 to 8.06 cm, fruit diameter from 6.96 to 8.64 cm, weight of 100 arils from 34.35 to 47.76 g, and aril number from 357.94 to 466.15 fruit^{-1}. Because these attributes were all

greater under the same treatment that produced the highest yield, the results indicate that the yield advantage was associated with enhancement of fruit size and aril development in addition to fruit retention. The physiological interpretation is consistent with complementary functions of the three inputs: micronutrients support enzyme activity, photosynthetic metabolism and reproductive development; GA_3 promotes cell division and expansion; and the biofertiliser component may contribute to nutrient acquisition and sustained plant growth. Foliar micronutrient studies in pomegranate have likewise reported improvements in fruit physical characteristics and yield, while recent work confirms that nutrient-based foliar programmes can improve both vegetative growth and reproductive performance (Hussein *et al*., 2024; Ahmed *et al*., 2024).

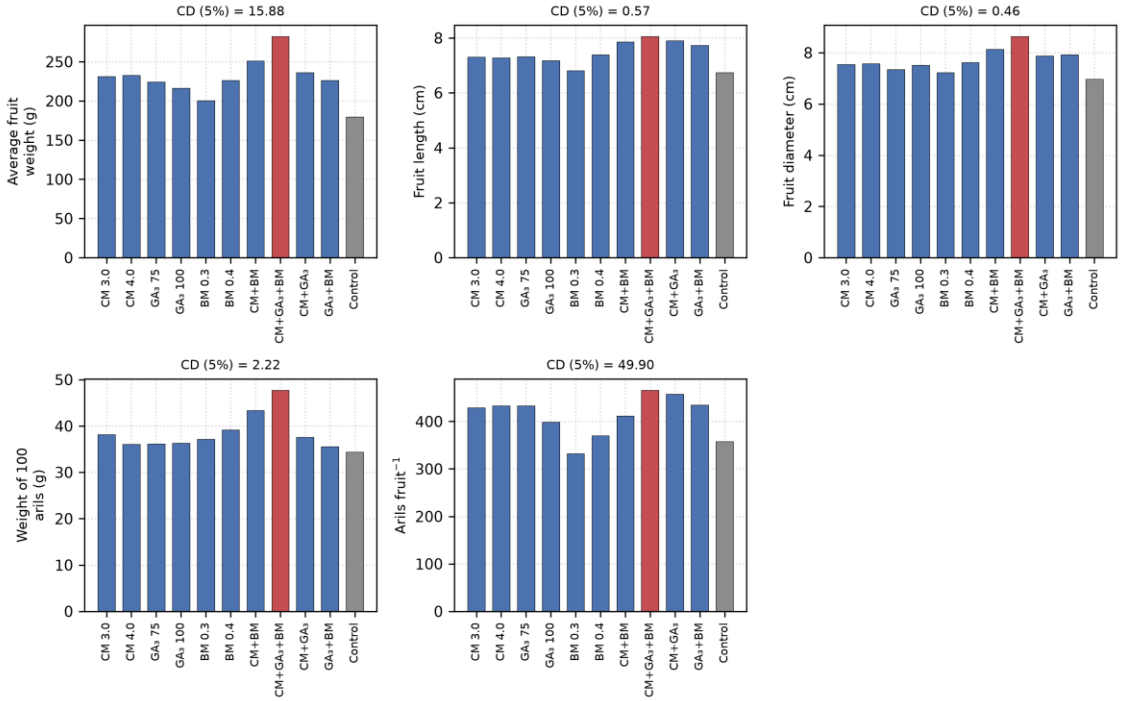


Fig. 5. Physical yield components of Bhagwa pomegranate, namely average fruit weight, fruit length, fruit diameter, weight of 100 arils and number of arils per fruit, as influenced by foliar treatments (pooled means). The critical difference at the 5 per cent level is given above each panel.

Table 2. Plant height of Bhagwa pomegranate at 30, 60 and 90 days after flowering as influenced by propagation method and foliar treatments (pooled means of 2018–19 and 2019–20)

Treatment	Plant height at 30 DAF (cm)	Plant height at 60 DAF (cm)	Plant height at 90 DAF (cm)
Propagation method (P)			
Air-layered plants (P_1)	183.11	212.71	241.13
Tissue-cultured plants (P_2)	147.33	171.47	198.36
S.E. ±	*1.16*	*1.17*	*1.52*
C.D. at 5%	*3.41*	*3.42*	*4.49*
Nutrient treatment (N)			
N_1: Chelated micronutrients @ 3.0 g L^{-1}	160.54	188.56	218.48
N_2: Chelated micronutrients @ 4.0 g L^{-1}	158.66	184.20	213.37
N_3: GA_3 @ 75 ppm	168.59	197.37	225.47
N_4: GA_3 @ 100 ppm	172.88	201.90	226.04
N_5: Biomix @ 0.3%	164.16	193.18	219.78
N_6: Biomix @ 0.4%	154.36	183.17	210.28
N_7: Chelated micronutrients @ 3.0 g L^{-1} + Biomix @ 0.3%	170.15	200.49	230.52
N_8: Chelated micronutrients @ 3.0 g L^{-1} + GA_3 @ 75 ppm + Biomix @ 0.3%	199.31	226.51	255.53
N_9: Chelated micronutrients @ 3.0 g L^{-1} + GA_3 @ 75 ppm	178.44	204.25	231.52
N_{10}: GA_3 @ 75 ppm + Biomix @ 0.3%	146.72	171.30	198.66
N_{11}: Control (water spray)	143.65	162.06	187.57
S.E. ±	*2.72*	*2.73*	*3.58*
C.D. at 5%	*7.99*	*8.03*	*10.52*
C.D. at 5% (P × N)	*11.31*	*11.35*	*14.88*

DAF = days after flowering; S.E. = standard error of the mean; C.D. = critical difference; NS = non-significant.

Table 3. Number of branches per plant, number of leaves per branch and stem girth of Bhagwa pomegranate as influenced by propagation method and foliar treatments (pooled means)

Treatment	Branches plant^{-1}	Leaves branch^{-1}	Stem girth (cm)
Propagation method (P)			
Air-layered plants (P_1)	13.76	960.63	15.67
Tissue-cultured plants (P_2)	12.46	900.74	13.98
S.E. ±	*0.07*	*2.01*	*0.08*
C.D. at 5%	*0.22*	*5.91*	*0.22*
Nutrient treatment (N)			
N_1: Chelated micronutrients @ 3.0 g L^{-1}	12.01	880.08	13.56
N_2: Chelated micronutrients @ 4.0 g L^{-1}	12.34	915.10	14.49
N_3: GA_3 @ 75 ppm	13.22	989.66	15.09
N_4: GA_3 @ 100 ppm	14.60	1011.5	16.03
N_5: Biomix @ 0.3%	11.89	836.68	14.15
N_6: Biomix @ 0.4%	11.68	844.62	14.43
N_7: Chelated micronutrients @ 3.0 g L^{-1} + Biomix @ 0.3%	12.65	859.69	15.44
N_8: Chelated micronutrients @ 3.0 g L^{-1} + GA_3 @ 75 ppm + Biomix @ 0.3%	16.58	1097.8	17.23
N_9: Chelated micronutrients @ 3.0 g L^{-1} + GA_3 @ 75 ppm	15.52	1036.5	15.67
N_{10}: GA_3 @ 75 ppm + Biomix @ 0.3%	12.19	959.83	13.98
N_{11}: Control (water spray)	11.51	806.02	13.04
S.E. ±	*0.18*	*4.72*	*0.18*
C.D. at 5%	*0.52*	*13.84*	*0.52*
C.D. at 5% (P × N)	*0.73*	*19.59*	*0.73*

Table 4. Canopy spread of Bhagwa pomegranate in the north–south (N–S) and east–west (E–W) directions as influenced by propagation method and foliar treatments (pooled means)

Treatment	N–S at 30 DAF (cm)	N–S at 60 DAF (cm)	N–S at 90 DAF (cm)	E–W at 30 DAF (cm)	E–W at 60 DAF (cm)	E–W at 90 DAF (cm)
Propagation method (P)						
Air-layered plants (P_1)	160.25	162.38	178.02	180.76	207.19	206.37
Tissue-cultured plants (P_2)	147.08	146.96	165.04	168.09	191.35	195.53
S.E. ±	*2.24*	*3.51*	*3.29*	*3.21*	*2.66*	*4.33*
C.D. at 5%	*6.58*	*10.39*	*9.67*	*9.42*	*7.81*	*12.71*
Nutrient treatment (N)						
N_1: Chelated micronutrients @ 3.0 g L^{-1}	167.88	167.86	181.54	186.70	200.16	207.07
N_2: Chelated micronutrients @ 4.0 g L^{-1}	143.69	148.53	164.32	162.99	197.58	194.94
N_3: GA_3 @ 75 ppm	150.08	147.45	169.25	164.22	186.63	180.07
N_4: GA_3 @ 100 ppm	139.10	140.15	152.30	152.04	179.02	178.72
N_5: Biomix @ 0.3%	152.64	144.21	162.13	168.91	184.10	193.01
N_6: Biomix @ 0.4%	151.26	157.55	176.54	181.98	200.13	206.54
N_7: Chelated micronutrients @ 3.0 g L^{-1} + Biomix @ 0.3%	158.87	145.96	169.33	159.88	196.31	195.19
N_8: Chelated micronutrients @ 3.0 g L^{-1} + GA_3 @ 75 ppm + Biomix @ 0.3%	160.63	162.46	179.99	185.02	212.34	218.21
N_9: Chelated micronutrients @ 3.0 g L^{-1} + GA_3 @ 75 ppm	172.14	174.96	189.03	196.54	224.29	219.91
N_{10}: GA_3 @ 75 ppm + Biomix @ 0.3%	150.63	160.15	179.28	187.67	220.28	222.81
N_{11}: Control (water spray)	143.41	152.10	163.15	172.72	191.31	193.97
S.E. ±	*5.26*	*8.23*	*7.72*	*7.52*	*6.24*	*10.15*
C.D. at 5%	*15.44*	*NS*	*22.68*	*22.09*	*18.32*	*29.80*
C.D. at 5% (P × N)	*21.84*	*34.47*	*32.09*	*31.25*	*25.91*	*42.14*

Table 5. Flowering behaviour of Bhagwa pomegranate as influenced by propagation method and foliar treatments (pooled means)

Treatment	Days to flowering initiation	Days to 50% flowering	Flowers plant^{-1}	Male flowers plant^{-1}	Sex ratio
Propagation method (P)					
Air-layered plants (P_1)	42.96	24.52	184.91	95.95	45.35 (26.97)
Tissue-cultured plants (P_2)	44.25	25.67	174.22	91.32	43.80 (25.99)
S.E. ±	*0.16*	*0.09*	*0.52*	*0.37*	*0.06*
C.D. at 5%	*0.48*	*0.27*	*1.51*	*1.08*	*0.18*
Nutrient treatment (N)					
N_1: Chelated micronutrients @ 3.0 g L^{-1}	42.98	25.18	170.42	90.06	43.30 (25.65)
N_2: Chelated micronutrients @ 4.0 g L^{-1}	42.43	23.25	172.29	91.73	43.24 (25.63)
N_3: GA_3 @ 75 ppm	45.08	25.29	179.95	94.17	44.91 (26.68)
N_4: GA_3 @ 100 ppm	43.53	23.66	185.72	96.59	45.25 (26.90)
N_5: Biomix @ 0.3%	44.88	26.92	174.89	86.68	47.33 (28.25)
N_6: Biomix @ 0.4%	44.13	25.68	173.70	87.58	44.62 (26.50)
N_7: Chelated micronutrients @ 3.0 g L^{-1} + Biomix @ 0.3%	41.57	25.14	175.46	94.02	43.30 (25.66)
N_8: Chelated micronutrients @ 3.0 g L^{-1} + GA_3 @ 75 ppm + Biomix @ 0.3%	41.35	23.45	195.43	106.62	42.59 (25.22)
N_9: Chelated micronutrients @ 3.0 g L^{-1} + GA_3 @ 75 ppm	40.57	22.30	189.87	101.49	44.54 (26.45)
N_{10}: GA_3 @ 75 ppm + Biomix @ 0.3%	43.74	26.13	181.68	95.28	44.48 (26.41)
N_{11}: Control (water spray)	49.40	29.08	175.81	85.73	46.78 (27.90)
S.E. ±	*0.38*	*0.21*	*1.21*	*0.87*	*0.15*
C.D. at 5%	*1.12*	*0.62*	*3.55*	*2.54*	*0.43*
C.D. at 5% (P × N)	*1.58*	*0.88*	*5.02*	*3.59*	*0.61*

Figures in parentheses in the sex-ratio column are the corresponding transformed values used for analysis

Table 6. Fruit set, fruit drop and number of fruits retained at harvest in Bhagwa pomegranate as influenced by propagation method and foliar treatments (pooled means)

Treatment	Fruit set plant^{-1}	Fruits dropped plant^{-1}	Fruit drop (%)	Fruits plant^{-1} at harvest
Propagation method (P)				
Air-layered plants (P_1)	79.72	2.86	3.58 (2.05)	69.78
Tissue-cultured plants (P_2)	73.53	2.59	3.55 (2.03)	62.96
S.E. ±	*0.19*	*0.09*	*0.07*	*0.21*
C.D. at 5%	*0.57*	*0.27*	*0.20*	*0.63*
Nutrient treatment (N)				
N_1: Chelated micronutrients @ 3.0 g L^{-1}	70.90	2.15	3.04 (1.74)	61.46
N_2: Chelated micronutrients @ 4.0 g L^{-1}	72.30	2.59	3.66 (2.10)	66.30
N_3: GA_3 @ 75 ppm	78.03	2.53	3.26 (1.87)	66.53
N_4: GA_3 @ 100 ppm	81.52	2.71	3.33 (1.91)	70.94
N_5: Biomix @ 0.3%	79.78	3.02	3.79 (2.17)	69.66
N_6: Biomix @ 0.4%	74.49	2.79	3.75 (2.15)	61.74
N_7: Chelated micronutrients @ 3.0 g L^{-1} + Biomix @ 0.3%	73.70	2.17	2.95 (1.69)	62.93
N_8: Chelated micronutrients @ 3.0 g L^{-1} + GA_3 @ 75 ppm + Biomix @ 0.3%	76.44	2.80	3.71 (2.13)	65.51
N_9: Chelated micronutrients @ 3.0 g L^{-1} + GA_3 @ 75 ppm	78.92	2.87	3.47 (1.99)	66.29
N_{10}: GA_3 @ 75 ppm + Biomix @ 0.3%	78.00	2.51	3.25 (1.86)	69.63
N_{11}: Control (water spray)	78.80	3.87	4.96 (2.84)	69.07
S.E. ±	*0.46*	*0.22*	*0.16*	*0.50*
C.D. at 5%	*1.34*	*0.64*	*0.47*	*1.47*
C.D. at 5% (P × N)	*1.90*	*0.91*	*0.66*	*2.08*

Figures in parentheses in the fruit-drop column are angular-transformed values

Table 7. Yield per plant and yield per hectare of Bhagwa pomegranate as influenced by propagation method and foliar treatments (pooled means)

Treatment	Yield plant^{-1} (kg)	Yield (t ha^{-1})
Propagation method (P)		
Air-layered plants (P_1)	15.37	11.37
Tissue-cultured plants (P_2)	14.66	10.85
S.E. ±	*0.16*	*0.12*
C.D. at 5%	*0.47*	*0.35*
Nutrient treatment (N)		
N_1: Chelated micronutrients @ 3.0 g L^{-1}	14.21	10.52
N_2: Chelated micronutrients @ 4.0 g L^{-1}	15.19	11.24
N_3: GA_3 @ 75 ppm	14.83	10.98
N_4: GA_3 @ 100 ppm	15.29	11.32
N_5: Biomix @ 0.3%	13.94	10.31
N_6: Biomix @ 0.4%	13.98	10.34
N_7: Chelated micronutrients @ 3.0 g L^{-1} + Biomix @ 0.3%	15.67	11.60
N_8: Chelated micronutrients @ 3.0 g L^{-1} + GA_3 @ 75 ppm + Biomix @ 0.3%	18.27	13.52
N_9: Chelated micronutrients @ 3.0 g L^{-1} + GA_3 @ 75 ppm	15.68	11.60
N_{10}: GA_3 @ 75 ppm + Biomix @ 0.3%	15.70	11.61
N_{11}: Control (water spray)	12.40	9.18
S.E. ±	*0.38*	*0.28*
C.D. at 5%	*1.10*	*0.82*
C.D. at 5% (P × N)	*1.56*	*1.16*

4. Conclusion

The two-season field experiment showed that foliar nutrient and growth-regulator treatments were associated with differences in vegetative growth, flowering and fruit yield in Bhagwa pomegranate. Among the eleven treatments evaluated, three sprays of chelated micronutrients at 3.0 g L^{-1}, GA_3 at 75 ppm and Biomix at 0.3%, applied at 45, 90 and 135 days after flowering, produced the highest pooled yield of 18.27 kg per plant, compared with 12.40 kg per plant in the water-sprayed control. This represented a yield increase of 47.3%. The same combination produced the greatest plant height, branch number, leaf number per branch and stem girth, as well as a lower fruit-drop percentage than the control. However, GA_3 at 100 ppm gave the greatest fruit set and number of fruits retained at harvest, showing that yield and fruit number did not follow identical treatment rankings. Air-layered trees also outperformed tissue-cultured trees for several growth and yield attributes. These findings identify a promising treatment under the specific orchard and seasonal conditions tested. Evaluation across additional locations and spray programmes would be necessary before wider recommendations are made.

5. Limitations

The experiment was undertaken at one orchard in Parbhani over two mrig bahar seasons, using five-year-old Bhagwa pomegranate trees and two replications. Consequently, the findings may not extend directly to other cultivars, growing regions, tree ages or management conditions. All foliar treatments followed the same three-spray schedule, so the study cannot determine whether alternative application timings or frequencies would provide similar results. The observed responses should therefore be interpreted within the tested treatment concentrations, propagation methods and field conditions.

Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. Grammarly and ChatGPT were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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