Print ISSN : 0972-8813
e-ISSN : 2582-2780
[Vol. 23(1) January-April 2025]

Pantnagar Journal of Research

(Formerly International Journal of Basic and Applied Agricultural Research ISSN : 2349-8765)

G.B. Pant University of Agriculture & Technology, Pantnagar

PANTNAGAR JOURNAL OF RESEARCH

Vol. 23(1) January-April 2025

CONTENTS

Nutrients enhancing flowering characteristics in Mango (*Mangifera indica* cv. Dashehari) under medium density planting

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ABSTRACT: The experiment was conducted in mango cv. Dashehari planted in medium density at the Horticulture Research Centre, Pattharchatta, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, during 2023-24. The objective of the study was to assess the effect of different nutrient doses on mango flowering traits. The experiment was laid out in RBD (Randomized Block Design) with 10 treatments consisting of 3 replications. Our study revealed that the earliest panicle emergence (1st February to 8th February), higher flowering duration (25.83 days), flowering intensity (51.22 %), panicle length (32.68 cm), number of hermaphrodite flowers (395.41), wider panicle width (14.54 cm), and lowest sex ratio (0.82) were observed in T8 (75% RDF /tree/year basin application after harvest + two foliar sprays of 0.50 % Ferric sulfate + 0.50 % Calcium chloride + 0.50% Zinc sulfate + 0.10% Boric acid just before flowering and marble stage. Therefore, T8 may be recommended in mango cv. Dashehari under medium-density planting for higher panicle, flowering and sex characteristics, which ultimately improve fruit yield.

Keywords: Foliar application, flowering duration, hermaphrodite flowers, panicle emergence

One of the most important tropical fruits in the world, mango has been grown for more than 4,000 years and spread to tropical and subtropical regions across the world, with the Philippines, China, India, and Thailand being the main producers (Rajan and Hudedamani, 2019). Although there are still many wild populations in the Assam region between India and Burma (now Myanmar), the mango is native to the lower Himalayan slopes and even to regions near Nepal or Bhutan (Abraham and Peter, 2007). This plant is thought to have been domesticated 6000 years ago and has been cultivated since prehistoric times. Today, it is grown in more than 100 nations in tropical and subtropical regions, ranging from 33° south latitude in South Africa to 36° north latitude in Spain. With an annual yield of over 40% (20.77 million tons) from an area of over 2.29 million hectares, India is the world's largest producer of mangoes (Balaganesh and Makarabbi, 2023).

Despite mango being one of the major crops at both national and global levels, nutritional scarcity problems influence the quality and productivity of the crop (Ganeshamurthy *et al.*, 2018). This is because the cultivation of the mango crop under medium-density planting is the complexity of the nutrient interaction between the plant and soil. Macro and micronutrients do not act independently; their interaction can result in synergetic or antagonistic effects, making it difficult to isolate the impact of individual nutrients on specific flowering attributes. Environmental variability is another noteworthy challenge. Factors such as temperature, humidity, rainfall, and soil type can influence nutrient availability and plant uptake, leading to inconsistency in growth and development.

Different flowering attributes of mango, from panicle emergence to full bloom, are influenced by nutritional and environmental factors. Plants that receive adequate nitrogen, zinc, and boron exhibit early reproductive growth, leading to the earliest panicle emergence. However, excessive nitrogen during this stage can lead to excessive vegetative growth at the expense of flowering (Hamlin and Mills, 2001). Earliest panicle emergence marks the beginning of the flowering phase, enabling the plant to initiate reproductive growth sooner, which often leads to an extended fruit development period. This early emergence enhances the chances of a higher fruit set by allowing better synchronization with favorable for better pollination and fertilization.

As a vital macronutrient, phosphorus supports energy transfer through ATP and enhances metabolic processes critical for panicle initiation and early emergence. Adequate phosphorus availability promotes the timely differentiation of floral buds, ensuring early panicle development and extending the flowering duration by sustaining the energy demands of the flowering process. Phosphorus and zinc boost flowering intensity, providing ample nectar and pollen, which supports pollinators and encourages them to visit other plants. This, in turn, improves pollination and fruit set in surrounding vegetation (Hasan *et al*., 2016). Potassium and boron further improve the duration of flowering, resulting in prolonged pollen availability, which enhances cross-pollination, especially in orchards where pollinator activity is crucial (Alebidi *et al*., 2023). Essential micronutrients such as boron, zinc, iron, copper, and calcium are critical for floral initiation, panicle development, and reproductive success. Boron is particularly important for early panicle emergence as it facilitates cell division, pollen tube growth, and carbohydrate translocation, ensuring timely and synchronized flowering (Aasim *et al*., 2022). Zinc supports the synthesis of growth hormones like auxins, which promote panicle elongation and increase panicle size, while iron is integral to photosynthesis and enzyme activation, providing the energy required during the flowering phase. Copper enhances reproductive processes by improving pollen viability and reducing flower drop, which prolongs the flowering duration and supports sustained reproductive activity. Calcium supports cell wall integrity, and its availability during flowering aids in reducing flower drop, thus enhancing fruit set (Maurya *et al.,* 2023). The availability of micronutrients plays an important role in determining the sex ratio by enhancing the proportion of hermaphrodite flowers, which are essential for fruit sets, as compared to male flowers. Deficiencies in any of these micronutrients can result in delayed panicle emergence, reduced panicle size, shortened flowering periods, and imbalanced sex ratios, thereby limiting fruit yield and quality.

Keeping in view the above facts, an experiment was conducted with the objective of evaluating the effect of nutrient treatments on key flowering attributes of mango, including early panicle emergence, higher flowering duration, flowering intensity, panicle size, and sex ratio under medium-high-density planting systems. The study aimed to identify the specific nutrient requirements and their interactions that enhance flowering performance and, the proportion of hermaphrodite flowers, which ultimately leads to higher fruit set and yield.

MATERIALS AND METHODS

Experiment site and metrological data

The present investigation was conducted on thirteen years old mango cv. Dashehari during two consecutive production cycles (i.e., 2022-23 and 2023-24) at Horticulture Research Center G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand (India). The experimental site was located at 29° 07' N and 79° 47' E. Mean weekly high and low air temperatures (39.4! & 6.0!), relative humidity (39% evening & 18.7% morning), and average weekly rainfall (34.9 mm) were recorded during the experiment (2022-24).

Experimental design and management

Under Medium High-Density Planting, the experiment was set up in a randomized block design with three replications spaced 5 m apart and ten treatments. Figure 1 The application of micronutrients was done by soil application (October) and one foliar spray was done just before the flowering, using 15 liters of water for a fully grown-up tree for each foliar spray. However, the quantity of spray solution may vary with the age and canopy volume. The micronutrients were dissolved first in a small quantity of water and made up to the required volume of spray solution. Shampoo sachets or any other commercially available stickers can be added to the spray solution to increase the effectiveness and the addition of lemon/lime juice also helps to increase the efficiency of uptake. The recommended doses of farm yard manure @ 50 kg per tree and fertilizers (RDF: 1000 g N: 750 g P: 1000 g K kg/tree) were applied during October-November, except nitrogen, which is applied after flowering. The sources of fertilizers and micronutrients were urea, SSP: single super phosphate and MOP: murate of potash, zinc sulfate, copper sulfate, calcium chloride, manganese sulfate, ferrous sulfate and boric acid/borax.

Treatment details

The 10 treatments consisting of the recommended dose of fertilizer, macro (primary nutrients), micronutrient, and their combinations were selected to see the effect on the flowering of mango cv. Dashehari. The treatments consists T_1: Control as per 100% RDF(1000gN + 750gP2O5 + 1000g K_2O + 50 kg FYM /tree/year) in the basin after harvest, T_2 : 75% RDF + 100g Ferric sulfate + 100g Copper sulfate + 100g Zinc sulfate +50g Boric acid/tree/ year (soil application) in the basin after harvest + one foliar spray of 0.50% Ferric sulfate+ 0.50% Calcium chloride+ 0.50% Zinc sulfate+ 0.10% Boric acid at marble size growth stage, T_3: 50% RDF + 100g Ferric sulfate + 100g Copper sulfate + 100g Zinc sulfate +50g Boric acid/tree/year (soil application) in the basin after harvest + one foliar spray of 0.50% Ferric sulfate+ 0.50% $CaCl_2$+ 0.50% Zinc sulfate + 0.10% Boric acid at marble size growth stage, T_4: 25% RDF + 100g Ferric sulfate + 100g Copper sulfate + 100g Zinc sulfate +50g Boric acid/tree/year (Soil application) in the basin after harvest + one foliar spray of 0.50% Ferric sulfate+ 0.50% Calcium chloride+ 0.50% Zinc sulfate+ 0.10% Boric acid at marble size growth stage, T_5 : 75% RDF + 100g Ferric sulfate + 100g Copper sulfate + 100g Zinc sulfate +50g Boric acid/tree/ year (soil application) in the basin after harvest + two foliar sprays of + 0.50% Ferric sulfate+ 0.50% Calcium chloride+ 0.50% Zinc sulfate+ 0.10% Boric acid at just before flowering and marble stage, T_6: 50% RDF + 100g Ferric sulfate + 100g Copper sulfate + 100g Zinc sulfate +50g Boric acid/tree/ year (soil application) in the basin after harvest + two foliar sprays of + 0.50% Ferric sulfate+ 0.50% Calcium chloride+ 0.50% Zinc sulfate+ 0.10% Boric acid at just before flowering and marble stage, T_7 : 25% RDF + 100g Ferric sulfate + 100g Copper sulfate + 100g Zinc sulfate +50g Boric acid/tree/ year (soil application) in the basin after harvest + two foliar sprays of 0.50% Ferric sulfate+ 0.50% Calcium chloride+ 0.50% Zinc sulfate+ 0.10% Boric acidat just before flowering and marble stage, T_8 : 75% RDF /tree/year (soil application) in the basin after harvest + two foliar sprays of 0.50% Ferric sulfate + 0.50% Calcium chloride+ 0.50% Zinc sulfate + 0.10% Boric acidjust before flowering and marble stage), T_9: 50% RDF /tree/year (soil application) in the basin after harvest + two foliar sprays of 0.50% Ferric sulfate + 0.50% Calcium chloride + 0.50% Zinc sulfate + 0.10% at just before flowering and marble stage, T_{10}: 25% RDF + tree/ year (soil application) in the basin after harvest + two foliar sprays of 0.50% Ferric sulfate + 0.50% Calcium chloride + 0.50% Zinc sulfate + 0.10% at just before flowering and marble stage.

Observations

Panicle and flowering characteristics

Regular inspections were conducted on alternate days during the month of February to record the date of the first panicle appearance. Visual observations of each tree were conducted from the second fortnight of February to the second fortnight of March 2023-24 to record the date of the initiation of flowering and full bloom. Flowering duration is considered as the number of days from the day of panicle initiation to the full bloom. The number of shoots and flowering panicles in a square meter area was counted to determine the flowering intensity. The number of flowering panicles divided by the number of shoots per m^2 gives the flowering intensity percentage. The length of ten randomly marked panicles was measured in centimeters with the help of a measuring scale.

Flower sex behaviors

Bags of perforated oil paper were used to count the many kinds of flowers. The lower part was linked with the panicle that held the shoots when they were expanded upward. To prevent flower loss, the bags were secured vertically. Natural pollination was also made easier by the panicle's unhindered access to sunlight, air, and insects. Every day, flowers were counted by opening the bag's lower side in different Petridis. We counted the average number of hermaphrodite and staminate blooms in each panicle. The sex ratio was calculated as staminate flowers divided by hermaphrodite flowers.

Data analysis

The data were examined using the Randomized Block Design analytical process. The F-variance test was used to do analysis of variances (ANOVA) for the characters after the mean values for each parameter were determined.

RESULTS AND DISCUSSION

Panicle emergence

Results showed that panicle emergence, flowering initiation, full bloom and flower intensity varied across treatments (Table 1). The earliest panicle emergence (1st February to 8th February in 2023 and 19th February to 3rd March in 2024) was observed with the treatment T8 (75% RDF /tree/year basin application after harvest + two foliar sprays of 0.50% Ferric sulfate + 0.50% Calcium chloride + 0.50% Zinc sulfate + 0.10% Boric acid just before flowering and marble stage), as compared to control (26th February to 2 March in 2023 and 28th February to 4th - March in 2024).

The earliest initiation of flowering (12th February to 20th February in 2023 and 8th March to 16th March in 2024) and full bloom (24th February to 4th March in 2023 and 10th March to 26th March in 2024) was observed with the treatments of T_9 which was closed to T_8, while control had significantly delayed flowering of mango. The data presented in Figure 2 shows that T8 exhibited the highest flowering duration (25.83 days), which was statistically at par with T_6 (24.50 days), followed by T_9 (23.17 days) and T_{10} (23.33 days). In contrast, the shortest flowering period (18.67 days) was noticed with the treatment of control (T_1) during both experimental years. Similarly, the highest flowering intensity (51.22%) was recorded with the treatment of T_8, which was statistically at par with T_9 (47.45) and T_5 (47.37), followed by T_7 (44.95%), whereas, the lower flowering intensity (33.47%) with the treatment of T_1 (RDF). These results highlight the efficacy of nutrient strategies involving a reduced dose of RDF, supplemented with foliar sprays containing ferric sulfate, calcium chloride, zinc sulfate, and boric acid applied at critical stages pre-flowering. This outcome aligns with prior findings by (Mondal and Bose, 2019), which demonstrated that micronutrients like zinc and boron improve auxin synthesis and carbohydrate metabolism, crucial for earlier panicle development. They emphasized the necessity of a continuous and balanced supply of nutrients to support the metabolic demands of reproductive transitions. Additionally, including micronutrients such as calcium and boron could have enhanced enzymatic activity and cell wall development, promoting timely panicle emergence and flowering, as reported by Ray *et al.* (2024). The early flowering can be attributed to the nutrient regime involving either 75% RDF combined with two foliar sprays containing ferric sulfate, calcium chloride, zinc sulfate, and boric acid at critical phenological stages. These results align with studies by Kirkby *et al.* (2023), which demonstrated that a balanced supply of micronutrients, especially zinc and boron, accelerates reproductive transitions by enhancing auxin and gibberellin biosynthesis and improving photosynthate partitioning. This delay is consistent with findings by Ramírez and Davenport (2010), which highlighted the importance of nutrient availability for timely floral induction and reproductive development in mango. A maximum flowering period in T_8 may indicate a more synchronized and efficient floral development process, likely facilitated by its nutrient strategy of 75% RDF supplemented with micronutrient-enriched foliar sprays at key developmental stages. This aligns with the findings of Kumar *et al.* (2020), who reported that targeted micronutrient supplementation enhances the efficiency of physiological processes like floral differentiation and synchrony, leading to compressed flowering windows. The superior flowering intensity in T_8 can be attributed to the optimized availability of nutrients like Zn and Bo, which are critical for reproductive organ development and pollination success (Pandey, 2010). Furthermore, using calcium chloride in foliar sprays may have contributed to improved cell wall integrity and flower retention, factors that enhance flowering intensity (Mazumder *et al.*, 2021). The control treatment (T_1), with its reliance on 100% RDF applied only as a soil amendment without additional micronutrient support, likely experienced

Table 1: Effect of soil and foliar application of nutrients on panicle emergence, start of flowering, full bloom, and flowering intensity in mango cv. Dashehari

Treatments	Date of panicle emergence		Date starts of flowering		Date of full bloom		Flowering intensity (%)		
	2023	2024	2023	2024	2023	2024	2023	2024	Mean
T_1	26- February to 2- March	28-Feb to 4-March	13- March to 15- March	11-March to 13-March	17-March to 21- March	18- March to 20- March	33.00^{d}	33.93^{e}	33.47^{e}
T_2	13- February to 27- February	22- Feb to 1-March	27- February to 13 March	8-March to 12-March	10- March to 28- March	17- March to 20- March	35.89^{bcd}	40.32^{cde}	38.11^{cde}
T_3	10- February to 28- February	27-Feb to 1-March	23- February to 9- March	11-March to 15-March	10- March to 20- March	20- March to 23- March	38.68^{bcd}	42.92^{bcde}	40.80^{bcd}
T_4	3- February to 28 February	21-Feb to 28-Feb	11-March to 20- March	9-March to 11-March	24- March to 29- March	18- March to 19- March	41.14^{abcd}	47.58^{abc}	44.36^{abc}
T_5	24- Feb to 1- March	23- Feb to 29-Feb	10- March to 14- March	9-March to 12-March	21- March to 28-March	15- March to 19- March	43.18^{abc}	51.56^{ab}	47.37^{ab}
T_6	25- February to 28- February	24-Feb to 3-March	9- March to 13- March	11-March to 13-March	21- March to 26- March	21- March to 23-March	43.33^{abc}	44.44b^{cd}	43.89^{bc}
T_7	20-February to 28-February	27-Feb to 3-March	10- March to 12 March	11-March to 16-March	17- March to 18- March	19- March to 24- March	42.35^{abcd}	47.54^{abc}	44.95^{abc}
T_8	1- Feb to 8-Feb	19-Feb to 3-March	17- Feb to 24- Feb	8-March to 16-March	26- Feb to 11- March	10- March to 26- March	48.56^{a}	53.89^{a}	51.22^{a}
T_9	2 February to 8 February	23-Feb to 27 Feb	12- February to 20- February	9-March to 16-March	24- February to 4- March	18- March to 23- March	43.94^{ab}	50.96^{ab}	47.45^{ab}
T_{10}	9- February to 26- February	19-Feb to 28- Feb	26- February to 12 March	7-March to 11-March	8- March to 27- March	14- March to 17- March	33.89^{cd}	37.98^{de}	35.93^{de}
C.D. (at 5%)	-	-	-	-	-	-	8.73	8.34	6.36

*See the treatment details in material methods.

nutrient imbalances or suboptimal availability during critical flowering phases. This could explain the prolonged yet less intense flowering period. Studies by Muneer *et al.* (2024) emphasize that excessive reliance on macro-nutrients without micronutrient fortification can lead to inefficient resource utilization, resulting in prolonged flowering durations but reduced overall intensity.

Panicle dimension

Results showed significant differences among panicle dimensions (Table 2). The highest panicle length (32.68 cm) was recorded with T8 (75% RDF /tree/ year (soil application) in the basin after harvest + two foliar sprays of 0.50% Ferric sulfate + 0.50% Calcium chloride + 0.50% Zinc sulfate + 0.10% Boric acid just before flowering and marble stage), followed by T_9 (29.20 cm). The shortest panicle length (21.87 cm) was recorded with T_1 (RDF). The higher panicle width (15.88 cm) was recorded in T5 (75% RDF + 100g Ferric sulfate + 100g Copper sulfate + 100g Zinc sulfate +50g Boric acid/tree/ year (soil application) in the basin after harvest + two foliar sprays of + 0.50% Ferric sulfate + 0.50% Calcium chloride + 0.50% Zinc sulfate + 0.10% Boric acid at just before flowering and marble stage), followed by T_8 (14.54 cm) whereas, the shortest panicle width (10.91 cm) was recorded with the treatment of T_1 (RDF). These results suggest that the balanced and timely nutrient supply of nutrients (T_8) facilitated optimal cell division and elongation, critical processes driving panicle growth. Zinc and boron, key components of the foliar sprays, are known to enhance hormonal activity, particularly auxin and gibberellin synthesis, which are vital for

Table 2: Effect of soil and foliar application of nutrients on panicle length, staminate flowers, hermaphrodite flowers, and total number of flowers per panicle in mango cv. Dashehari

Treatments	Panicle size (cm) length 2023	length 2024	length Mean	width 2023	width 2024	width Mean	Number of staminate flowers panicle^{-1} 2023	2024	Mean	Number of hermaphrodite flowers panicle^{-1} 2023	2024	Mean	Total number of flowers per panicle 2023	2024	Mean
T_1	22.5^{g}	21.23^{f}	21.87^{f}	11.20^{d}	10.62^{e}	10.91^{d}	460.00^{b}	443.45^{ab}	451.72^{b}	216.08^{f}	192.80^{e}	204.44^{g}	676.07^{d}	636.25^{e}	656.16^{d}
T_2	24.60^{ef}	24.28^{e}	24.44^{e}	12.25^{cd}	10.04^{e}	11.15^{d}	502.25^{a}	450.92^{a}	476.58^{a}	280.89^{f}	290.10^{f}	285.49^{h}	716.23^{c}	612.77^{e}	664.50^{d}
T_3	26.12^{cde}	25.74^{cde}	25.93^{cd}	13.00^{bcd}	12.90^{cd}	12.95^{c}	442.54^{bc}	440.15^{ab}	441.35^{bc}	272.98^{d}	275.10^{c}	274.04^{d}	715.52^{c}	715.25^{bc}	715.38^{c}
T_4	25.25^{de}	25.12^{de}	25.19^{de}	12.50^{cd}	12.40^{cd}	12.45^{cd}	440.31^{cd}	429.60^{b}	434.96^{cd}	213.97^{d}	237.32^{c}	225.65^{d}	721.21^{c}	715.69^{bc}	718.45^{c}
T_5	26.90^{cd}	27.3^{c}	27.10^{c}	15.24^{a}	16.53^{a}	15.88^{a}	426.51^{cdef}	431.17^{b}	428.84^{de}	387.74^{e}	394.97^{d}	391.35^{f}	668.62^{d}	668.49^{d}	668.55^{d}
T_6	27.15^{c}	26.9^{c}	27.03^{c}	13.25^{bc}	13.45^{bc}	13.35^{bc}	432.15^{cde}	354.83^{e}	393.49^{g}	376.40^{b}	274.12^{c}	325.26^{c}	808.56^{a}	628.95^{e}	718.75^{c}
T_7	26.09^{cde}	26.14^{cd}	26.12^{cd}	13.24^{bc}	13.07^{bc}	13.16^{bc}	421.34^{def}	406.13^{c}	413.74^{f}	228.30^{ef}	161.85^{e}	195.07^{e}	649.63^{d}	696.23^{c}	672.93^{d}
T_8	32.30^{a}	33.05^{a}	32.68^{a}	14.38^{ab}	14.70^{b}	14.54^{ab}	409.46^{f}	245.65^{f}	327.56^{h}	400.29^{a}	390.54^{a}	395.41^{a}	809.75^{a}	640.62^{e}	725.18^{c}
T_9	28.85^{b}	29.55^{b}	29.20^{b}	13.10^{bcd}	13.60^{bc}	13.35^{bc}	414.05^{ef}	429.14^{b}	421.59^{ef}	242.10^{ab}	286.10^{a}	264.10^{a}	801.78^{a}	819.69^{a}	810.74^{a}
T_{10}	23.25^{fg}	22.55^{f}	22.90^{f}	11.63cd	11.28^{de}	11.45^{d}	433.10^{cde}	387.73^{d}	410.41^{f}	333.15^{c}	352.48^{b}	342.82^{b}	766.25^{b}	740.21^{b}	753.23^{b}
C.D. (at 5%)	1.61	1.62	1.19	1.66	1.63	1.39	17.94	16.10	10.92	18.85	18.18	12.59	19.10	19.16	15.74

*See the treatment details in material methods

meristematic tissue activity and panicle elongation (Al-Karawi and Habeeb 2024). This aligns with the finding by Oliveira *et al.* (2020), which emphasizes the critical role of micronutrients in enhancing floral organ development and promoting larger panicles in mango. Calcium chloride, included in the foliar sprays, may have contributed to structural integrity and resistance to abiotic stresses during panicle development (Chowdhury *et al.*, 2019). Furthermore, the wider panicle width in T8 likely provided a larger surface area for floral development and potentially enhanced pollination efficiency, factors crucial for yield optimization.

Flower sex behaviors

It was found that there is a significant effect of treatments on flower sex characteristics of mango (Table 2). A higher staminate blooms per panicle (476.58) was observed with T2 (75% RDF + 100g Ferric sulfate + 100g Copper sulfate + 100g Zinc sulfate + 50g Boric acid/tree/year (soil application) in the basin after harvest + one foliar spray of 0.50% Ferric sulfate + 0.50% Calcium chloride + 0.50% Zinc sulfate + 0.10% Boric acid at marble size growth stage), followed by T_1 (451.72). The minimum number of staminate flowers (357.56) was recorded with the treatment of T_9. The maximum number of hermaphrodite flowers/panicles (395.41) was observed in T_8, whereas the lowest was noted in T_7 (195.07). The higher total number of flowers per panicle (725.18) was recorded in T_8, followed by T_{10} (753.23), whereas the lowest (656.16) was recorded in T_1 (RDF). This result suggests that the nutrient regimen in T2 effectively supported male floral development, potentially through enhanced nitrogen metabolism and zinc-mediated enzymatic activity critical for pollen formation (Rymbai *et al.*, 2016). In contrast, T_9, with 50% RDF and two foliar sprays, exhibited the lowest number of staminate flowers, indicating that a reduced RDF without sufficient soil-applied micronutrients might limit male gametophyte production. For hermaphrodite flowers, T_8 emerged as the most effective treatment, producing the highest mean, while T_7 recorded the lowest. This pronounced difference underscores the influence of foliar-applied nutrients at key developmental stages. The dual foliar sprays in T_8 likely ensured a sustained supply of critical elements such as boron and calcium, essential for ovule development, pollen viability, and fertilization processes (Jehangir *et al.,* 2017). The importance of boron in enhancing carbohydrate transport and hormonal balance, especially during reproductive development, has been well-documented (Kohli *et al.,* 2023). This comprehensive floral advantage in

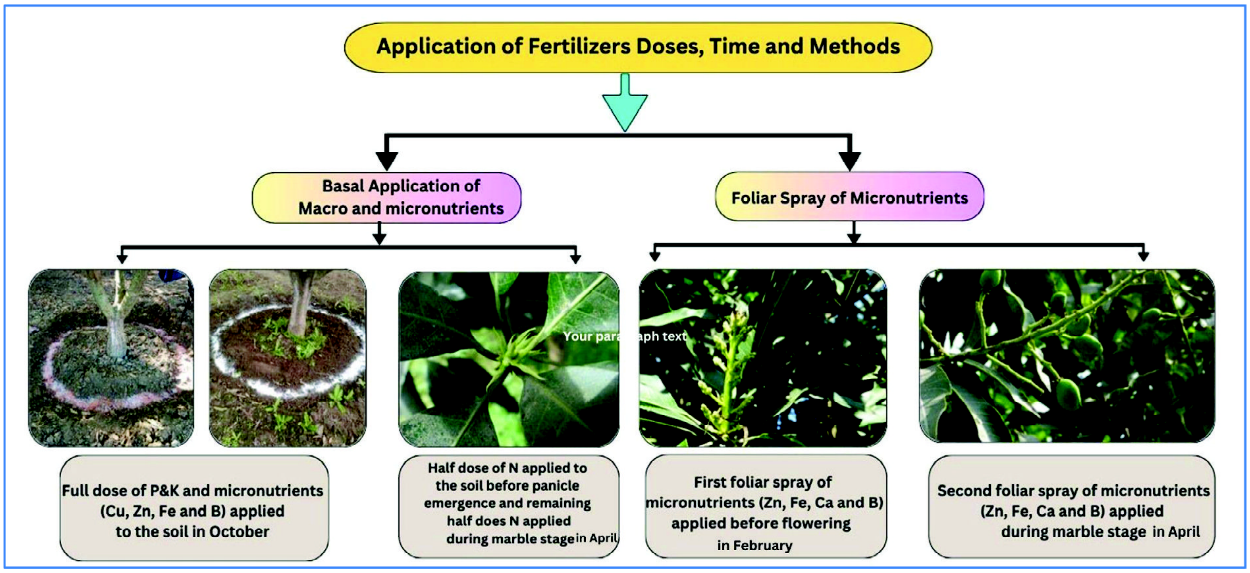

Fig. 1: **Overview of Fertilizer Doses, Timing, and Application Methods for Mango crop**

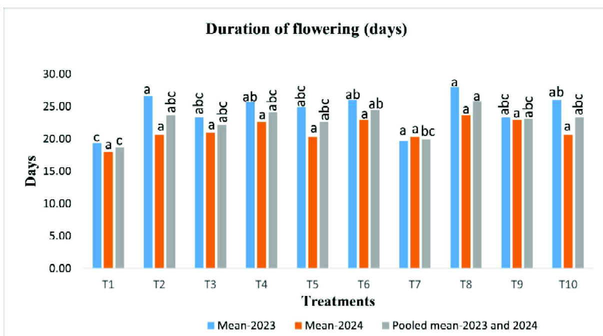

Fig. 2: Effect of soil and foliar application of nutrients on flowering duration (days) in mango cv. Dashehari

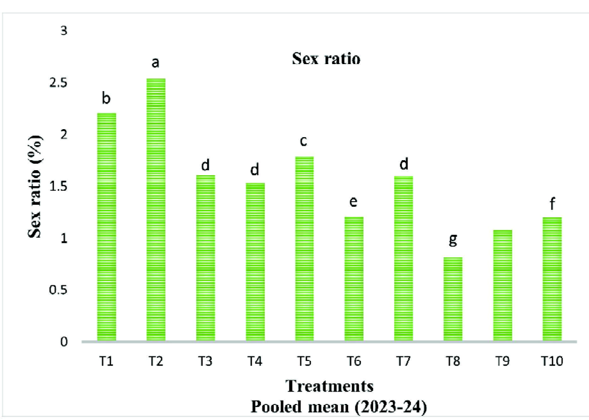

Fig. 3: Effect of soil and foliar application of nutrients on sex ratio in mango cv. Dashehari

T_8 can be attributed to its nutrient strategy, which combines moderate RDF levels with strategic foliar sprays that enhance overall flower production and improve the proportion of functional (hermaphrodite) flowers. Such a balance is crucial for fruit set and yield optimization, as hermaphrodite flowers are directly responsible for fruit production. Sex ratio, representing the balance of staminate to hermaphrodite flowers varied significantly across treatments as shown in Figure 3. The higher sex ratio was recorded in T8 (0.82) followed by T_9 (1.08). Conversely, T_8 recorded the lowest sex ratio (0.82), reflecting a higher proportion of hermaphrodite flowers. This outcome suggests that while the nutrient regime of 75% RDF with micronutrient-enriched soil application and a single foliar spray supported floral differentiation, it favored staminate flower production over hermaphrodite flowers. This trend aligns with findings by Sood and Dwivedi (2015), which highlighted that excess nitrogen, can skew floral differentiation toward staminate flower formation due to its role in promoting vegetative growth and male gametophyte development. This outcome is indicative of a nutrient strategy that optimally supports the development of functional reproductive structures. The integration of 75% RDF with two foliar sprays rich in boron, calcium, zinc, and ferric sulfate likely enhanced hormonal balance and carbohydrate transport, both of which are crucial for the development of hermaphrodite flowers (Tadayon and Hosseini, 2023). Boron, in particular, role in cell wall formation and pollen tube growth, contributing to a higher prevalence of flowers capable of fruit set (Mousavi and Motesharezadeh, 2020).

CONCLUSION

Our studies showed that the application of 75% of the RDF (Recommended dose of fertilizers), combined with a foliar spray (0.50% Ferric sulfate, 0.50% Calcium chloride, 0.50% Zinc sulfate, and 0.10% Boric acid) in mango cv. Dashehari under medium-density planting at stages just before flowering is highly effective in enhancing panicle, flowering and sex characteristics, which ultimately improve fruit yield. Furthermore, applying about 25% reduced fertilizer dose not only improves the efficiency of nutrient utilization but also minimizes the environmental footprint and production costs, contributing to sustainable orchard management practices.

ACKNOWLEDGMENTS

The financial support and the extension of infrastructural facilities received from the Horticulture Research Centre, Pattarchatta, AICRP on Fruits & Department of Horticulture, GBPUA&T, Pantnagar, Uttarakhand (India) is duly acknowledged.

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Received: February 26, 2025
Accepted: March 13, 2025