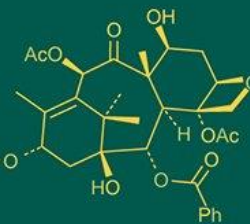
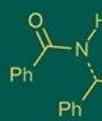


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Synergistic effect of urea, zinc and PGPR in enhancing panicle morphology, flower sex ratio and biomass attributes in mango cv. Langra

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Abstract

The yield of mangoes (*Mangifera indica* L.) is chiefly influenced by the equilibrium between reproductive and non-reproductive biomass, panicle vitality, and floral quality. Conversely, the specific impacts of integrated nutrition and biofertilizer management on panicle-level traits in conventional mango cultivars remain largely unknown. The present study, conducted from 2020 to 2021 at the Fruit Research Station, JNKVV, Jabalpur, employed a Factorial Randomized Block Design (FRBD) with 27 treatment combinations to evaluate the synergistic effects of urea (0%, 2%, 4%), zinc sulfate (0%, 0.5%, 1%), and PGPR (0%, 0.5%, 1%) on panicle morphology, flower sex ratio, malformation incidence, and biomass attributes in mango cv. Langra. When 4% urea, 1% zinc sulphate, and 1% PGPR (T₂₈: A₂B₂C₂) were applied topically, the highest ratio of hermaphrodite to male flowers (37.70), the most healthy panicles per m² (15.14), and the most fresh and dry weights of healthy panicles (37.89 g and 12.95 g, respectively) were all recorded. The same treatment, which had the lowest fresh weight of malformed panicles (45.08 g) and the fewest number of malformed panicles per m² (2.31), also showed that less biomass was being used for non-productive purposes. The improvements were thought to be due to PGPR-mediated physiological efficiency, better nutrient absorption, stronger vegetative growth, and a balance of hormones (auxin and cytokinin). Treatment effects that were statistically significant at the 5% level showed that they were accurate and reliable. The combined treatment of urea, zinc, and PGPR improved the floral biology and reproductive efficiency of mango cv. Langra by successfully changing the way biomass was divided between deformed and healthy reproductive structures. This plan has a lot of potential to sustainably increase the yields of commercial mango orchards.

Keywords: Nutrient, synergy, enhances, mango, panicle, productivity

1. Introduction

The mango (*Mangifera indica* L.), which is in the Anacardiaceae family, is very important for culture, nutrition, and business. It is also known as the "King of Fruits." It is very important for human health, especially in places where people are likely to be low in vitamin A, because it is high in carbs, dietary fiber, vitamins A and C, antioxidants, potassium, and phytochemicals (Rajan, 2021) [17]. Mango seeds, like cocoa butter, have lipid molecules that could be useful in cooking, medicine, and cosmetics. India is the world's largest mango producer, with about 2.3 million hectares of land under cultivation and an annual output of more than 20.9 million tons. However, productivity is still low (8-10 t/ha) compared to 15-20 t/ha in countries like Brazil and Israel (Indiastat, 2021) [14]. Mangoes are a big part of the agricultural economy and bring in a lot of money from exports. The United Arab Emirates, the United States, the United Kingdom, Qatar, and Kuwait are the main places where mangoes are sent (APEDA, 2023-24) [1]. Alphonso, Kesar, Dashehari, Chausa, Banganapalli, and Langra are all important commercial varieties. Good nutrition management is very important for getting better fruit quality and more of it. Nitrogen has a big effect on vegetative growth, photosynthetic efficiency, panicle initiation, flower creation, embryo development, and fruit retention. But too little nitrogen can stop flowering and fruit set, while too much nitrogen can make plants grow vegetatively instead of reproductively. To get the most mangoes, you need to manage nitrogen properly.

Zinc is an important micronutrient that is responsible for enzyme activation, auxin biosynthesis, gene regulation, reproductive development, and stress tolerance (Hafeez *et al.*, 2013) [13]. A lack of zinc can cause stunted growth, chlorosis, smaller leaves, and sterility. External zinc treatment is important for increasing panicle biomass, flower growth, and fruit set because about 64% of India's agricultural soils, especially calcareous soils, don't have enough zinc (Zia *et al.*, 2006) [3]. Plant Growth-Promoting Rhizobacteria (PGPR) are helpful microorganisms that make nutrients more available, fix nitrogen, dissolve phosphorus, make hormones (auxins, cytokinins, and gibberellins), produce siderophores, and boost systemic resistance. They reduce the need for chemical fertilizers while improving the quality of fruit, blooming, root and shoot growth, and the efficiency of nutrient use. But their success depends on things like the environment, how well they interact with local microorganisms, how well they fit in with host plants, and how well they survive. In fruit crops like apples, citrus, apricots, mulberries, and mangoes, PGPR has shown good results. There is not enough research on how macronutrients (urea), micronutrients (zinc sulfate), and PGPR work together to affect the floral sex ratio, panicle health, and biomass allocation in mango cv. Langra, even though there is strong conceptual evidence. Prior studies exclusively focused on aggregate flowering or fruit yield, neglecting variables such as the ratio of hermaphrodite to male flowers, the count of healthy versus deformed panicles per square meter, and the fresh and dry weights of productive compared to non-productive panicles.

To enhance productivity in mango cv. Langra within sustainable orchard conditions, this study aims to evaluate the effects of the combined application of urea, zinc sulfate, and PGPR on floral biology, panicle morphology, and reproductive biomass distribution.

2. Materials and Methods

The present investigation was conducted during the flowering seasons of 2020-2021 and 2021-2022 at the Fruit Research Station, Department of Horticulture, Imalia, Jawaharlal Nehru Krishi Vishwavidyalaya (JNKVV), Jabalpur, Madhya Pradesh, India, under subtropical conditions favorable for mango cultivation. Laboratory analysis related to floral and panicle parameters was carried out at the Department of Food Science and Technology, JNKVV, Jabalpur. The experiment was laid out using Factorial Randomized Block Design (FRBD) with three factors, replicated twice, and comprising a total of 27 treatment combinations. The experimental material consisted of 54 uniformly vigorous, healthy, and unpruned mango trees (cv. Langra), approximately 46 years of age, spaced at 12 m × 12 m, each tree serving as an experimental unit for treatment application. The trees were selected based on uniformity in growth, canopy spread, and past bearing performance. Standard agronomic practices, including irrigation, pest management, and cultural operations, were uniformly applied throughout the experimental period.

There were 27 treatment combinations (3×3×3) that had three levels of each macronutrient (urea at 0%, 2%, and 4%), micronutrient (zinc sulfate at 0%, 0.5%, and 1.0%), and biofertilizer Plant Growth Promoting Rhizobacteria (PGPR at 0%, 0.5%, and 1.0%). Analytical-grade chemicals were used to make the nutrient solutions. To make a 2% urea solution, 20 g of urea was dissolved in 980 mL of

distilled water. The final volume was 1000 mL. In the same way, 40 g of urea made a 4% solution. Dissolving 5 g of ZnSO₄ in 995 mL of distilled water and 10 g of ZnSO₄ in 990 mL of distilled water made zinc sulfate solutions with concentrations of 0.5% and 1.0%. In the same way, 5 mL and 10 mL of the liquid formulation were mixed with distilled water to make 1000 mL of PGPR solutions with concentrations of 0.5% and 1.0%. It was decided that 15 liters of spraying solution per tree would be enough for consistent canopy coverage if these stock solutions were properly increased.

We used a manual power sprayer to apply treatments to the leaves twice. The first spray was given when the flowers were just starting to bloom, and the second spray was given when they were 50% open. To make sure that spraying was done consistently and that the solution didn't drift, enough steps were taken. We picked ten random stems from each tree and tagged them so we could keep track of what we saw about the panicle and blooming traits. By manually counting both types of flowers on tagged panicles and using the following formula, we found the ratio of hermaphrodite to male flowers: The ratio is the number of hermaphrodite blooms divided by the number of male flowers. We randomly placed a 1 m² quadrat at four different places around each tree to count the number of healthy and deformed panicles per square meter. Then, they found the average.

We used an electronic scale to weigh the fresh weight of both healthy and deformed panicles after we randomly separated the marked panicles at the node. These panicles were cut and then dried in an oven at 60 ± 2 °C until they all weighed the same. An electronic scale was then used to find out how much they weighed when they were dry. To prevent external variability, uniform soil moisture, plant protection strategies, and cultural practices were upheld throughout the research.

We used Fisher's Analysis of Variance (ANOVA) and Factorial Randomized Block Design (FRBD) to look at the data we had in a statistical way. The F-test was employed to ascertain the significance of treatment effects at a 5% probability threshold. When the treatment effects were thought to be significant, the Critical Difference (CD) at the 5% level was used to compare the means. We also calculated the standard error of mean [SE (m)] and standard error of difference [SE (d)] to see how accurate and reliable the treatment comparison was. The results were counted using the usual methods for interpreting statistics.

3. Results and Discussion

The data presented in Table clearly demonstrate that the combined application of macronutrient (urea), micronutrient (zinc sulphate), and biofertilizer (PGPR) significantly influenced floral biology, panicle health, and biomass attributes in mango cv. Langra.

3.1 The ratio of male to hermaphrodite flowers in each panicle

As the levels of urea, zinc, and PGPR rose, the number of hermaphrodite flowers per panicle slowly increased. Treatment T₂₈ (A2B2C2: 4% urea + 1.0% ZnSO₄ + 1% PGPR) had the best flower sex ratio (37.70), which was much better than all the other treatments. It came after T₁₈ (36.82) and T₂₆ (36.20). The untreated control (T₁) had the lowest value, with a ratio of 27.71. This means that using

nitrogen, zinc, and PGPR together makes plants more fertile by making hermaphrodite flowers grow. Zinc-induced hormonal control, PGPR-mediated auxin and cytokinin production, and better nitrogen availability for protein synthesis may all lead to better floral differentiation and fertility. These findings align with earlier research conducted by Ramirez and Davenport (2010) [18] and Bashan *et al.* (2014) [16], which emphasized the role of nutrient-microbe synergy in regulating mango fertility and flowering.

3.2 Number of malformed panicle (m²)

There was a big drop in the number of deformed panicles per square meter when integrated nutrition management was used. The control T₁ had the most deformed panicles (4.51 m²), while T₂₈ had the least (2.31 m²). T₁₈ (2.37 m²) and T₂₆ (2.45 m²) were next. The decreasing malformation trend with nutrition and PGPR integration shows that physiological recovery is better, nutrient absorption is more balanced, and floral meristem growth is better. PGPR enhances disease resistance through induced systemic resistance (ISR), potentially reducing the incidence of deformity, whereas zinc is crucial for preserving meristem integrity. This corroborates the findings of Sharma *et al.* (2020) and Ansari *et al.* (2015), which indicated that microbial inoculants and micronutrients significantly reduced mango malformation.

3.3 Number of healthy panicle (m²)

The combined treatment of nutrition and PGPR led to a big rise in the number of healthy panicles per square meter. The most healthy panicles were in T₂₈ (15.14 m²), then T₁₈ (14.87), and then T₁₇ (14.23). The least healthy panicles

were in control T₁ (9.77 m²). The increased production of healthy panicles under nutrient-rich treatments is due to better canopy health, more photosynthetic activity, and better assimilate translocation. Zinc helps flowers start to grow, nitrogen helps plants grow stronger, and PGPR makes better use of nutrients. All of these things lead to more panicle formation and better flower quality. This corresponds with the research conducted by Ahmad *et al.* (2018) [2] and Khoso *et al.* (2024) [16], which elucidated the synergistic effects of nutrients and PGPR on enhancing reproductive indices.

3.4 Fresh weight of healthy panicles

The fresh weight of healthy panicles also went up a lot when they got combined nutrition treatments. The healthy panicles in T₁ weighed the least (20.05 g), while those in T₂₈ weighed the most (37.89 g), followed by those in T₁₈ (36.40 g) and T₁₇ (35.61 g). Better absorption of nutrients, a higher capacity for holding water, and the development of active reproductive tissue could all be reasons why the panicle biomass is higher with these treatments.

3.5 Fresh weight of malformed panicles (g)

The fresh weight of malformed panicles dropped a lot with integrated treatments. T₂₈ had the lowest fresh weight (45.08 g), followed by T₁₈ (46.56 g) and T₂₄ (49.92 g). This is compared to control T₁ (69.41 g). This decrease suggests that the treatments diverted assimilates towards more resilient floral structures and suppressed unproductive sink biomass, or deformed panicles. Singh *et al.* (2021) found that deformed panicles gain structural biomass but can't reproduce, which fits with this.

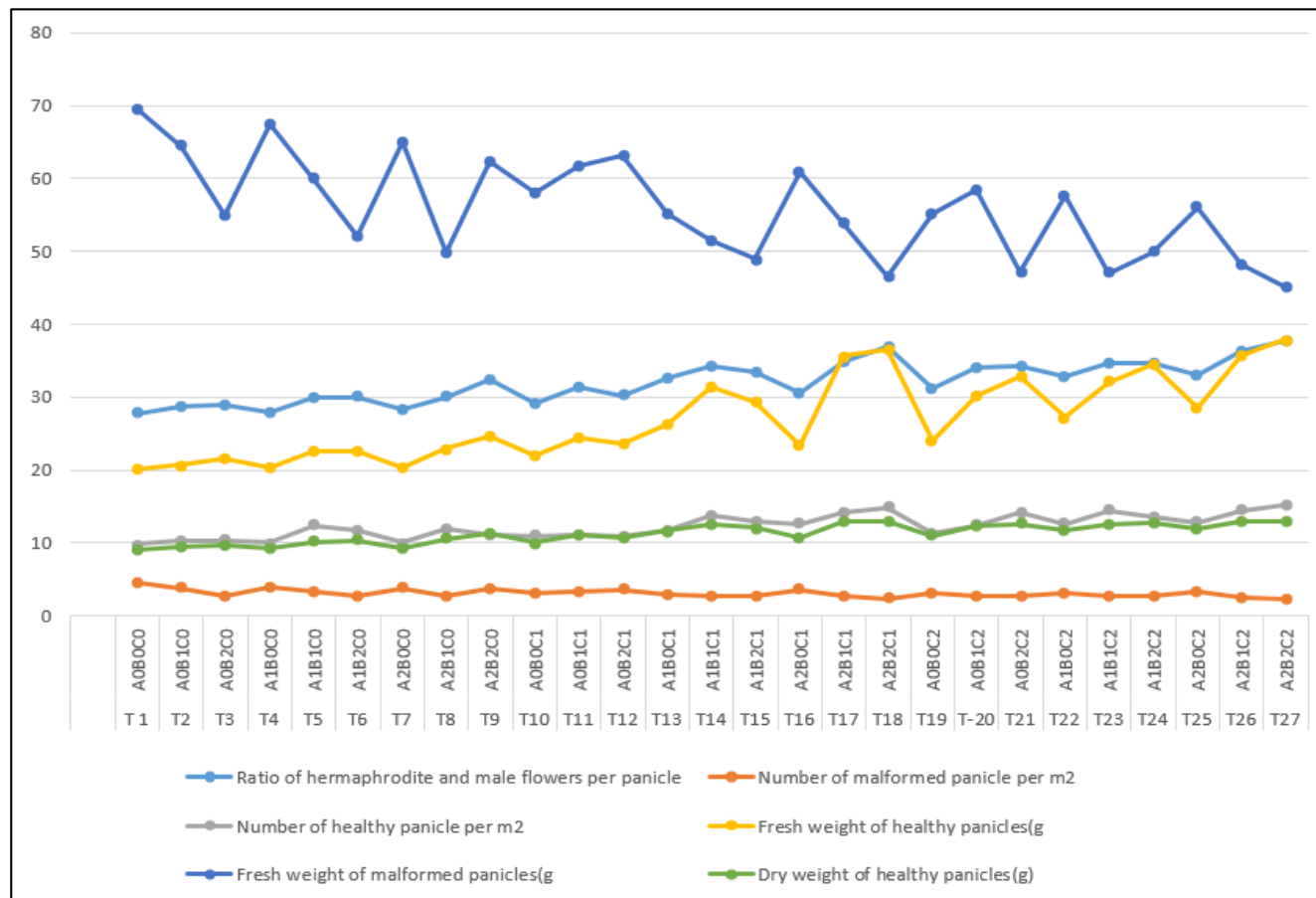


Fig 1: Synergistic Effect of Urea, Zinc and PGPR in Enhancing Panicle Morphology, Flower Sex Ratio and Biomass Attributes in Mango cv. Langra
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Table 1: Synergistic Effect of Urea, Zinc and PGPR in Enhancing Panicle Morphology, Flower Sex Ratio and Biomass Attributes in Mango cv. Langra

Treatments	Symbol	Ratio of hermaphrodite and male flowers per panicle	Number of malformed panicle per m ²	Number of healthy panicle per m ²	Fresh weight of healthy panicles (g)	Fresh weight of malformed panicles (g)	Dry weight of healthy panicles (g)
T ₁	A0B0C0	27.71	4.51	9.77	20.05	69.41	9.12
T ₂	A0B1C0	28.81	3.74	10.17	20.64	64.44	9.52
T ₃	A0B2C0	28.91	2.73	10.36	21.53	54.95	9.71
T ₄	A1B0C0	27.91	3.92	9.98	20.35	67.4	9.19
T ₅	A1B1C0	29.88	3.33	12.38	22.54	59.88	10.11
T ₆	A1B2C0	30.01	2.67	11.76	22.64	52.15	10.29
T ₇	A2B0C0	28.29	3.75	9.98	20.37	65	9.31
T ₈	A2B1C0	30.01	2.61	11.99	22.9	49.86	10.51
T ₉	A2B2C0	32.33	3.71	11.1	24.68	62.25	11.31
T ₁₀	A0B0C1	29.12	3.11	10.97	21.9	58.02	10.01
T ₁₁	A0B1C1	31.43	3.3	10.99	24.48	61.72	11.1
T ₁₂	A0B2C1	30.21	3.59	10.78	23.51	63.17	10.73
T ₁₃	A1B0C1	32.55	2.97	11.78	26.28	55.1	11.63
T ₁₄	A1B1C1	34.18	2.71	13.79	31.34	51.43	12.43
T ₁₅	A1B2C1	33.37	2.77	12.98	29.38	48.94	12.06
T ₁₆	A2B0C1	30.53	3.59	12.62	23.31	60.95	10.6
T ₁₇	A2B1C1	34.93	2.59	14.23	35.61	53.8	12.83
T ₁₈	A2B2C1	36.82	2.37	14.87	36.4	46.56	12.87
T ₁₉	A0B0C2	31.14	3.05	11.37	23.97	55.2	10.97
T ₂₀	A0B1C2	33.94	2.75	12.37	30.08	58.47	12.28
T ₂₁	A0B2C2	34.2	2.66	14.17	32.85	47.14	12.61
T ₂₂	A1B0C2	32.79	3.18	12.57	27.24	57.59	11.76
T ₂₃	A1B1C2	34.64	2.7	14.39	32.03	46.98	12.53
T ₂₄	A1B2C2	34.57	2.66	13.54	34.47	49.92	12.77
T ₂₅	A2B0C2	32.97	3.29	12.78	28.53	56	11.93
T ₂₆	A2B1C2	36.2	2.45	14.36	35.77	48.11	12.85
T ₂₈	A2B2C2	37.7	2.31	15.14	37.89	45.08	12.95
SE(m) ±		0.19	0.007	0.015	0.22	0.24	0.011
CD 5%		0.56	0.02	0.043	0.63	0.71	0.032

3.6 Dry weight of healthy panicles (g)

The healthy panicles' dry weight followed a similar pattern: T₂₈ had the most (12.95 g), T₁₈ had the second most (12.87 g), and T₂₆ had the third most (12.85 g). T₁ had the least (9.12 g). The increase in dry matter accumulation under integrated nutrient management shows that tissue growth is stronger, nutrient deposition is better, and reproductive competence is better. The shift from unproductive to productive biomass was further substantiated by the inverse trend in the dry weight of malformed panicles, which peaked in the control group (T₁) and diminished in T₂₈ (45.08 g).

The low standard errors [SE(m) ±] for all parameters and the critical difference (CD) values for flower ratio (0.56), malformed panicles (0.02), healthy panicles (0.043), fresh weight of healthy panicles (0.63), fresh weight of malformed panicles (0.71), and dry weight of healthy panicles (0.032) showed that the differences between treatments were statistically significant at the 5% level. This confirms that treatment comparisons are correct and reliable. The most effective foliar treatment for mango cv. Langra was 4% urea, 1% zinc sulfate, and 1% PGPR (T₂₈). This treatment improved floral sex expression, decreased panicle malformation, increased panicle biomass, and overall reproductive performance.

4. Conclusion

This research definitively demonstrates that enhancing reproductive efficiency, panicle morphology, and biomass distribution in mango cv. Langra necessitates the integrated foliar application of macronutrient (urea), micronutrient

(zinc sulfate), and biofertilizer (PGPR). Among all the treatment combinations, T₂₈ (4% urea + 1.0% ZnSO₄ + 1% PGPR) had the highest ratio of hermaphrodite to male flowers, the most healthy panicles per unit area, and the highest fresh and dry weights of productive panicles. T₂₈ had the lowest fresh weight of malformed structures and the fewest malformed panicles at the same time. This suggests a big change from unproductive to productive floral biomass. Zinc made enzymes work better, helped plants make auxin, made pollen last longer, and made tissues stronger. Nitrogen made plants grow better, helped plants photosynthesize better, and made flowers look different. PGPR helped plants move nutrients around, made hormones work better, and made roots and shoots more active. The positive effects of these treatments are thought to come from how they work together to help plants. This cumulative effect made it possible to improve the floral sex ratio, reduce panicle deformity, and encourage panicles that are stronger and healthier. The findings also show that the right nutrient-biofertilizer control can greatly increase reproductive potential by improving the morphological and functional aspects of panicle development. A big rise in healthy panicle biomass and a drop in malformed panicles show that assimilate partitioning is working well and that the plant's physiology is more balanced, both of which are necessary for more fruit set and potential production. Statistical analysis confirmed the importance of integrated nutrient management techniques in mango orchards, showing that these effects were very important and reliable. The foliar treatment of urea, zinc sulfate, and PGPR appears to be an effective, economical, and environmentally friendly way to

improve the quality of flowers, the health of panicles, and the production of reproductive organs in mango cv. Langra. This integrated approach could greatly improve the commercial production of mangoes, especially in subtropical orchards.

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