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Assessment of Foliar Application of Biostimulants and Silicon on Yield and Yield Attributing Characters of Mango (*Mangifera indica* l.) CV. Kesar

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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

The present investigation was carried out at Fruit Research Station, Sakkarbaug, Junagadh Agricultural University, Junagadh during 2020-21 and 2021-22. The experiment was laid out in Randomized Block Design with Factorial concept consisting two factors with three replications. The

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treatment comprised with biostimulants *viz*., without biostimulant, humic acid (1.5 %), panchagavya (3 %), seaweed extract (0.2 %), novel organic liquid fertilizer (2 %) and silicon *i.e*., without silicon, potassium silicate (0.2 %) and orthosilicic acid (0.2 %). The results of the study indicated that among the different biostimulants application of humic acid 1.5 % and among the different silicon application of potassium silicate 0.2 % was recorded with minimum number of nubbins per 100 fruits at pea (20.42 and 22.52) and marble stage (10.67 and 12.80) and maximum fruits retention at harvesting (2.03 and 1.85 %), number of fruits per tree (213.71 and 195.52), fruit yield (50.78 and 45.14 kg/tree), fruit length (10.60 and 10.39 cm), fruit breadth (6.67 and 6.55 cm), fruit weight (234.58 and 226.24 g), pulp weight (175.87 and 168.79 g) and pulp: stone ratio (5.16 and 5.07) during pooled analysis, respectively. In the present investigation some of the interaction effects were also found significant. The combined application of humic acid 1.5 % with potassium silicate 0.2 % recorded maximum number of fruits per tree (235.57), fruit yield (60.42 kg/tree), fruit length (11.06 cm), fruit breadth (96.86 cm), fruit weight (254.71 g) and pulp weight (192.61 g) during pooled analysis. It can be concluded that for improved yield and yield attributing characters with foliar application of humic acid 1.5 % along with potassium silicate 0.2 % at initiation of flowering, pea and marble stage.

Keywords: Biostimulants; silicon; mango; kesar; fruit yield.

1. INTRODUCTION

“Mango (*Mangifera indica* L.), a member of the Anacardiaceae family, is believed to have originated in the Indo-Burma region. Revered as the "King of Fruits", mangoes exhibit excellent adaptability. The genus *Mangifera* boasts as many as 69 valid species globally, with a staggering 11,595 cultivars documented worldwide. India boasts the largest repository of mango germplasm, with approximately 1,000 cultivars, a source of national pride” [1]. “Due to its exceptional flavor, delicious taste, delicate fragrance and attractive color, mango holds the esteemed position of being India's national fruit. India proudly leads the world as the largest producer of mangoes, with a production of 21,882 thousand MT cultivated across an area of 2,258 thousand hectares, achieving an impressive productivity rate of 9.70 MT per hectare” [2]. “The leading mango-growing states in India encompass Andhra Pradesh, Bihar, Gujarat, Uttar Pradesh, Maharashtra, Karnataka, Kerala, Tamil Nadu, Orissa and West Bengal. In Gujarat alone, mangoes are cultivated across a total area of 1,66,358 hectares, with a production of 1,22,2291 MT” [3,4,5,6]. “The cultivation is predominantly concentrated in districts like Valsad, Navsari, Surat, Bharuch, Rajkot, Jamnagar, Kutch and Junagadh, benefiting from the favorable agro-climatic conditions prevalent in these areas”. [7]

“A biostimulant is a substance or microorganism that, when applied to seeds, plants, or the rhizosphere, triggers natural processes to enhance or improve nutrient uptake, nutrient efficiency, tolerance to abiotic stress, or the overall quality and yield of crops” [8]. “Plant biostimulants are advocated as eco-friendly alternatives to chemical-based products. While the organic farming sector is a primary driver for these materials, the escalating demand from consumers for more sustainable crop production, coupled with a growing body of evidence supporting their beneficial properties, has led to their increasing popularity among conventional farmers. Additionally, pre-harvest application of biostimulants has emerged as an alternative approach to reduce reliance on chemical fertilizers”. [7]

“Silicon ranks as the eighth most prevalent element in nature and is the second most abundant element found in soil next to oxygen” [9]. “Despite not being officially recognized as essential for plant growth, its undeniable beneficial effects on growth and development have been widely observed across various plant species. Silicon plays a crucial role in plant biology by mitigating multiple stresses, both biotic and abiotic” [10]. “Alongside the naturally occurring soluble silicon in soil, many crops exhibit positive responses to supplemental silicon additions. Particularly in fruit crops, plants can absorb significant amounts of silicon, enhancing their mechanical strength. Beyond its structural function, silicon serves to shield plants from insect attacks, diseases and environmental stresses. In the realm of organic farming, applying silicon sources to fruit crops holds promise for increasing yields while reducing reliance on chemical fertilizers, pesticides and fungicides”. [7]

Effective fruit setting is crucial for the successful production of mango fruit. However, modern-day farmers are encountering challenges with poor fruit setting. Despite achieving good-quality fruit production on a commercial scale, they face various issues such as insufficient flowering, excessive fruit drop, undersized and irregular fruits and susceptibility to biotic and abiotic stresses, ultimately leading to poor yield. Particularly concerning is the significant drop observed in hermaphrodite flowers and young fruits, often exceeding 99%. Biostimulants serve to stimulate natural processes that improve nutrient uptake, efficiency and tolerance to abiotic stress, thereby enhancing crop quality and yield. Consequently, the application of biostimulants and silicon externally plays a crucial role in improving fruit setting, reducing fruit drop and enhancing both yield and quality.

Considering these factors, the present experiment is conducted to assess the effects of foliar application of biostimulants and silicon on the yield and yield attributing characters of mango (*Mangifera indica* L.) cv. Kesar.

2. MATERIALS AND METHODS

The current study was conducted at the Fruit Research Station, Sakkarbaug, College of Horticulture, Junagadh Agricultural University, Junagadh, during the years 2020-21 and 2021-22. The experiment was set up using a Randomized Block Design with a Factorial concept (FRBD), involving two factors with three replications and fifteen treatment combinations. The different treatments combinations were B_0S_0: Without biostimulant + Without silicon (Control), B_0S_1: Without biostimulant + Potassium silicate 0.2 %, B_0S_2: Without biostimulant + Orthosilicic acid 0.2 %, B_1S_0: Humic acid 1.5 % + Without silicon, B_1S_1: Humic acid 1.5 % + Potassium silicate 0.2 %, B_1S_2: Humic acid 1.5 % + Orthosilicic acid 0.2 %, B_2S_0: Panchagavya 3 % + Without silicon, B_2S_1: Panchagavya 3 % + Potassium silicate 0.2 %, B_2S_2: Panchagavya 3 % + Orthosilicic acid 0.2 %, B_3S_0: Seaweed extract 0.2 % + Without silicon, B_3S_1: Seaweed extract 0.2 % + Potassium silicate 0.2 %, B_3S_2: Seaweed extract 0.2% + Orthosilicic acid 0.2%, B_4S_0: Novel organic liquid fertilizer 2% + Without silicon, B_4S_1: Novel organic liquid fertilizer 2% + Potassium silicate 0.2%, B_4S_2: Novel organic liquid fertilizer 2% + Orthosilicic acid 0.2 %. The experimental material comprised 13-year-old grafted mango trees of the Kesar cultivar, which is considered the most significant commercial cultivar in the Saurashtra region. These trees were spaced at distances of 6 × 6 meters. A total of 45 uniform Kesar trees were selected for the experiment. The biostimulants and silicon solutions were prepared by dissolving them directly in water and then sprayed onto the mango trees using a foot sprayer. The spraying was carried out at the initiation of flowering, pea and marble stages of fruit development. It was ensured that the spraying was done on a clear and calm day during the morning hours to achieve the best effect. The spraying continued until the leaves and twigs were thoroughly wet, and droplets of the solution started trickling down. For observations, uniform, pest and disease-free panicles of mango were selected in different directions on each tree and tagged randomly. Two panicles were tagged in each direction (North, South, East, West), totaling eight panicles tagged on each tree. Observations on yield and yield attributing characters of each treatment were recorded and statistically analyzed.

3. RESULTS AND DISCUSSION

The outcomes of different treatments were documented and the results obtained during the investigation were thoroughly discussed, supported by reasoning and relevant references. The entirety of the results and discussion has been presented under the following headings:

3.1 Effect of Biostimulants

The investigation's findings revealed that the application of various biostimulants significantly influenced several parameters. These included the number of nubbins per 100 fruits at the pea and marble stages, fruit retention at harvesting (%), number of fruits per tree, fruit yield (kg/tree and t/ha), fruit length (cm), fruit breadth (cm), fruit weight (g), pulp weight (g), peel weight (g), stone weight (g) and pulp: stone ratio. These effects were observed across the years 2020-21 and 2021-22, as well as in the pooled data, as summarized in Tables 1, 2, 3, 5, 7, and 9 and depicted graphically in Fig. 1.

Significantly, minimum number of nubbins per 100 fruits at pea (19.52, 21.31 and 20.42) and marble stage (9.78, 11.57 and 10.67) and maximum fruit retention at harvesting (2.13, 1.93 and 2.03%), number of fruits per tree (236.34, 191.09 and 213.71), fruit yield (54.87, 46.69 and 50.78 kg/tree), fruit yield (15.25, 12.98 and 14.12 t/ha), fruit length (10.51, 10.69 and 10.60 cm), fruit breadth (6.64, 6.71 and 6.67 cm), fruit weight (229.68, 239.48 and 234.58 g), pulp weight (172.23, 179.50 and 175.87 g) and pulp:

stone ratio (5.16, 5.15 and 5.16) were recorded with the foliar application of humic acid 1.5% (B_1) during both the years as well as in pooled data analysis, respectively. Whereas, the minimum peel weight (21.75, 21.72 and 21.74 g) and stone weight (29.19, 29.13 and 29.16 g) was observed with the without spray of biostimulant (B_0) during both the years as well as in pooled analysis.

In the case of the number of nubbins per 100 fruits at the pea stage, treatment B_1 showed similar results to treatment B_2 across both years, as well as in the pooled analysis. Similarly, the number of nubbins per 100 fruits at the marble stage was comparable under treatment B_1 and treatment B_2 in the year 2021-22 only. Additionally, fruit length, fruit breadth, fruit weight and pulp weight obtained under treatment B_1 were statistically similar to treatment B_2 in the year 2020-21 exclusively. Pulp: stone ratio achieved under treatment B_1 was statistically equivalent to treatment B_2 and B_4 in both individual years and pooled data, while treatment B_3 exhibited this similarity in both years only. Conversely, the without biostimulants (B_0) resulted in poor performance across all aforementioned parameters in the years 2020-21, 2021-22 and in the pooled analysis.

The observed minimum number of nubbins per 100 fruits at both the pea and marble stages, as well as the maximum fruit retention at harvesting, can potentially be attributed to the positive influence of humic acid. Humic acid has been reported to exhibit behavior akin to auxins, as documented in previous studies [11]. This behavior includes delaying abscission, chelating metal ions under alkaline soil conditions and enhancing nutrient availability to plants [12]. The presence of humus substances within humic acid may have facilitated the mobilization of reserve food materials to the sink through increased activity of hydrolyzing and oxidizing enzymes. This process could have consequently improved the availability and utilization of nutrients by the plants. Given the calcareous nature and alkaline conditions of the soil, the efficiency of applied inorganic fertilizers tends to be low. However, the application of humic acid serves as a chelating agent for nutrients already present in the soil, thereby making them more accessible to plants. Recent scientific literature has demonstrated that humic acid can directly or indirectly affect various plant growth processes, including morphological, physiological, genetic and biochemical processes. The findings of this study align with those reported by Patel et al. [13], Momin et al. [14], Khattab et al. [15], Fatma et al. [16] and Hidayatullah et al. [17].

In the present investigation, the observed maximum number of fruits per tree and fruit yield (both in kg per tree and t/ha) could be attributed to the application of humic acid. Humic acid has been noted to increase the number of flowers per tree and enhance the rate of flower bud differentiation, ultimately leading to a higher average number of fruits per tree [18]. The superior mango yield observed may result from the cumulative effects of fruit length, breadth and weight. The positive impact of humic acid on mango yield in this study may be due to enhanced uptake of mineral nutrients and increased cation exchange in the soil. Additionally, the plant hormone-like activity of humic substances may contribute to increased mango yield [19]. These findings are consistent with previous studies conducted by Patel et al. [13], Momin et al. [14], Ngullie et al. [20], Sindha et al. [21], Khattab et al. [15], Abd El-Rahman [22], Popescu and Popescu [23], Laila et al. [24], Fatma et al. [16], Hidayatullah et al. [17] and Mahmoudi et al. [25].

The observed maximum fruit length, fruit breadth, fruit weight, pulp weight and pulp:stone ratio may be attributed to the improvement in plant nutrition facilitated by humic acid. Humic acid has been known to stimulate the absorption of mineral elements by promoting root growth and increasing the rate of mineral ion absorption on root surfaces, thereby facilitating their penetration into plant tissue cells. This promotes more active metabolism and increased respiratory activity in plants. Additionally, humic acid has been found to enhance the quantitative properties of fruit, such as fruit weight, breadth and length [26]. Moreover, humic acid plays a crucial role in releasing nutrients in the soil, making them more available to plants [27]. It achieves this by converting elements into forms suitable for assimilation by plants, acting as chelating agents and increasing the availability of major nutrients like phosphorus and other micronutrients [28]. The application of organic acids has been shown to increase fruit weight by activating hormones such as auxin and cytokinin, resulting in heavier fruits. Furthermore, foliar application of humic acid has been demonstrated to enhance fruit length by stimulating cell division and enlargement, thereby increasing the overall length of fruits [25]. Humic acid also stimulates plant enzymes and increases their production. These observations are consistent with earlier studies conducted by Patel et al. [13], Momin et al. [14], Ngullie et al. [20] and Abd El-Rahman [22].

3.2 Effect of Silicon

A similar trend to that of biostimulants was also observed with silicon and variations due to different silicon types were found to have a significant effect on various parameters. These parameters include the number of nubbins per 100 fruits at the pea and marble stages, fruit retention at harvesting (%), number of fruits per tree, fruit yield (both in kg per tree and t/ha), fruit length (cm), fruit breadth (cm), fruit weight (g), pulp weight (g), peel weight (g), stone weight (g) and pulp: stone ratio. These effects were consistent across the years 2020-21 and 2021-22, as well as in the pooled data, as presented in Tables 1, 2, 3, 5, 7, and 9 and depicted graphically in Fig. 1.

Significantly, minimum number of nubbins per 100 fruits at pea (21.57, 23.47 and 22.52) and marble stage (11.73, 13.87 and 12.80) and maximum fruit retention at harvesting (1.97, 1.73 and 1.85%), number of fruits per tree (215.17, 175.87 and 195.52), fruit yield (49.15, 41.14 and 45.14 kg/tree), fruit yield (13.66, 11.44 and 12.55 t/ha), fruit length (10.35, 10.43 and 10.39 cm), fruit breadth (6.56, 6.54 and 6.55 cm), fruit weight (224.62, 227.86 and 226.24 g), pulp weight (167.57, 170.02 and 168.79 g) and pulp: stone ratio (5.07, 5.07 and 5.07) were registered with an application of potassium silicate 0.2 % (S_1) during both the years as well as in pooled data analysis, respectively. Whereas, the minimum peel weight (22.27, 22.50 and 22.38 g) and stone weight (30.01, 30.31 and 30.16 g) was noted in without spray of silicon (S_0) during both the years as well as in pooled analysis, respectively.

In the case of the number of nubbins per 100 fruits at both the pea and marble stages, treatment S_1 exhibited similar results to treatment S_2 across both years, as well as in the pooled analysis. Similarly, fruit retention percentage at harvesting, fruit yield (both in kg per tree and t/ha) and fruit length obtained under treatment S_1 were comparable to treatment S_2 throughout both years. Fruit breadth recorded under treatment S_1 was also similar to treatment S_2 in individual years as well as in the pooled analysis. However, fruit weight and pulp weight recorded under treatment S_1 were comparable to treatment S_2 only in the year 2020-21. The pulp:stone ratio obtained under treatment S_1 was found to be comparable to treatment S_2 in individual years as well as in pooled data. Conversely, poor performance was noted in the treatment without silicon (S_0) across all the aforementioned parameters during the years 2020-21, 2021-22 and in the pooled data.

The observed maximum fruit retention at harvesting and the lowest number of nubbins per 100 fruits at both the pea and marble stages could be attributed to the role of silicon in mitigating the adverse effects of water stress and disorders on growth and fruiting. Additionally, silicon enhances the tolerance of trees to drought, aids in water transport and promotes root development. These findings align closely with previous studies conducted by Kachhadia et al. [29], Abd El-Rahman [30], Moawad et al. [31] and Masoud et al. [32].

The observed maximum number of fruits per tree and fruit yield (both in kg per tree and t/ha) may be attributed to silicon's role in promoting cell division, enhancing nutrient and water uptake and consequently leading to the production of a greater number of fruits. Potassium silicate has been noted for its positive effects on growth and yield, with increased yield being associated with enhanced photosynthetic activity, water metabolism, chlorophyll content, carbohydrate formation, membrane formation, lipid peroxidation and protective enzyme activity under drought conditions, along with increased uptake of essential nutrients [33]. The positive effects of silicon on growth characteristics and yield can be attributed to its crucial roles in improving plant growth, protecting plants against various stresses (such as drought, cold, disease and fungal attacks), alleviating abiotic stress (including heavy metal toxicity and salinity), enhancing root development and facilitating water, nutrient and pigment uptake [34, 35]. The increase in yield may be linked to an increase in fruit weight and the number of fruits per tree. Additionally, potassium may enhance carbohydrate accumulation through carbohydrate formation and translocation, while also regulating cell water content and photosynthetic activity. The beneficial influence of potassium on yield can also be attributed to its enhancement of various metabolic processes such as carbohydrate formation, translocation and accumulation, all of which contribute to yield development [36]. These results are consistent with findings reported by Moawad et al. [31], Ahmed et al. [27], Lalithya et al. [38] and Ali et al. [39].

The observed maximum fruit length, fruit breadth, fruit weight, pulp weight and pulp:stone ratio may be attributed to silicon's ability to enhance the structural stability of cell walls during cell elongation and division, thereby maintaining cell shape. This structural support is crucial for the function and survival of cells. Additionally, the increase in fruit dimensions may also be attributed to cell division during the initial stages and later to cell expansion associated with the movement of water and other metabolites into the cell, resulting in an overall increase in fruit weight and diameter. The increase in pulp weight may be due to the beneficial role of silicon in promoting the production of higher quantities of photosynthates and their translocation to the growing fruits. These results are consistent with findings reported by Jaishankar et al. [40] and Roshdy [41].

3.3 Interaction Effect of Biostimulants and Silicon

The interaction effect between biostimulants and silicon was found to be significant for various yield and yield-attributing characters, including the number of fruits per tree, fruit yield (both in kg/tree and t/ha), fruit length, fruit breadth, fruit weight and pulp weight during the years 2020-21, 2021-22 and in the pooled data. These results are summarized in Table 4, 6, 8 and Fig. 2. However, the interaction effect between biostimulants and silicon did not produce any significant effect on the number of nubbins per 100 fruits at the pea and marble stages, fruit retention percentage at harvesting, peel weight, stone weight, and pulp:stone ratio during both years, as well as in the pooled data.

Significantly, maximum number of fruits per tree (259.26, 211.88 and 235.57), fruit yield (64.66, 56.18 and 60.42 kg/tree) and fruit yield (17.97, 15.62 and 16.80 t/ha), fruit length (10.93, 11.20 and 11.06 cm), fruit breadth (6.82, 6.90 and 6.86 cm), fruit weight (247.78, 261.63 and 254.71 g), pulp weight (187.39, 197.83 and 192.61 g) were recorded in combined application of humic acid 1.5 % with potassium silicate 0.2% (B_1S_1) during both the years as well as in pooled data, respectively.

In terms of the number of fruits per tree, the treatment combination B_1S_1 was found to be comparable to the treatment combination B_1S_2 across both years and to the treatment combination B_2S_1 in the year 2021-22 only. Similarly, fruit yield (both in kg/tree and t/ha) under the treatment combination B_1S_1 was comparable to the treatment combination B_1S_2 in both years. Fruit length obtained under the treatment combination B_1S_1 was found to be similar to the treatment combination B_1S_2 and B_2S_1 in the year 2020-21 only. Fruit breadth recorded under the treatment combination B_1S_1 was comparable to the treatment combination B_1S_2 in individual years and in pooled data and to the treatment combination B_2S_1 and B_2S_2 in the year 2020-21 only. Fruit weight and pulp weight obtained under the treatment combination B_1S_1 were comparable to the treatment combination B_1S_2 in both years and to the treatment combination B_2S_1 and B_2S_2 in the year 2020-21 only. However, poor performance was observed in the treatment combination B_0S_0 (Control) across all the aforementioned characters during the years 2020-21, 2021-22, and in pooled data.

The maximum number of fruits per tree and fruit yield (both in kg/tree and t/ha) observed may be attributed to the positive interactive effect of humic acid with potassium silicate. The combined treatment of humic acid with potassium silicate likely facilitated better uptake of measured nutrients from calcareous soils. The increase in the number of fruits per tree and related characteristics due to the application of humic acid may be attributed to the availability of micro and macro nutrients to the plants, as well as an increase in hormonal activities within the plant. Silicon, on the other hand, may have contributed to cell division, enhanced nutrient and water uptake, resulting in the production of a greater number of fruits. Additionally, silicon plays a role in reinforcing plants to be tolerant to various environmental stresses such as salinity and drought, alleviating both biotic and abiotic stress, which could have had a positive impact on growth and fruiting activities. The results of the present study are consistent with the findings of previous research studies conducted by Patel et al. [13], Momin et al. [14], Ngullie et al. [20], Sindha et al. [21], Khattab et al. [15] and Abd El-Rahman [22] concerning humic acid and Kachhadia et al. [29], Ahmed et al. [37] and Lalithya et al. [38] concerning potassium silicate.

The significantly observed maximum fruit length, fruit breadth, fruit weight and pulp weight could be attributed to the combined treatment of humic acid with potassium silicate, resulting in improved uptake of measured nutrients from calcareous soils. This effect may be due to humic substances ability to chelate metal ions, such as Fe and Zn, which are retained in exchangeable form in the soil. These forms of nutrients are readily absorbed by plants, leading to enhanced metabolic activity that likely contributed to the increase in physical parameters of the fruits. Additionally, the silicon source may have induced higher photosynthetic activity, resulting in increased translocation of metabolites, thereby enhancing fruit length and breadth. Moreover, silicon may have facilitated cell division, enhanced nutrient and water uptake, thereby enhancing the physical attributes of the fruits. These findings are consistent with earlier reports by Patel et al. [13], Momin et al. [14], Ngullie et al. [20] and Abd El-Rahman [22] regarding humic acid and by Abd El-Rahman [30], Moawad et al. [31], Lalithya et al. [38] and Roshdy [41] regarding potassium silicate.

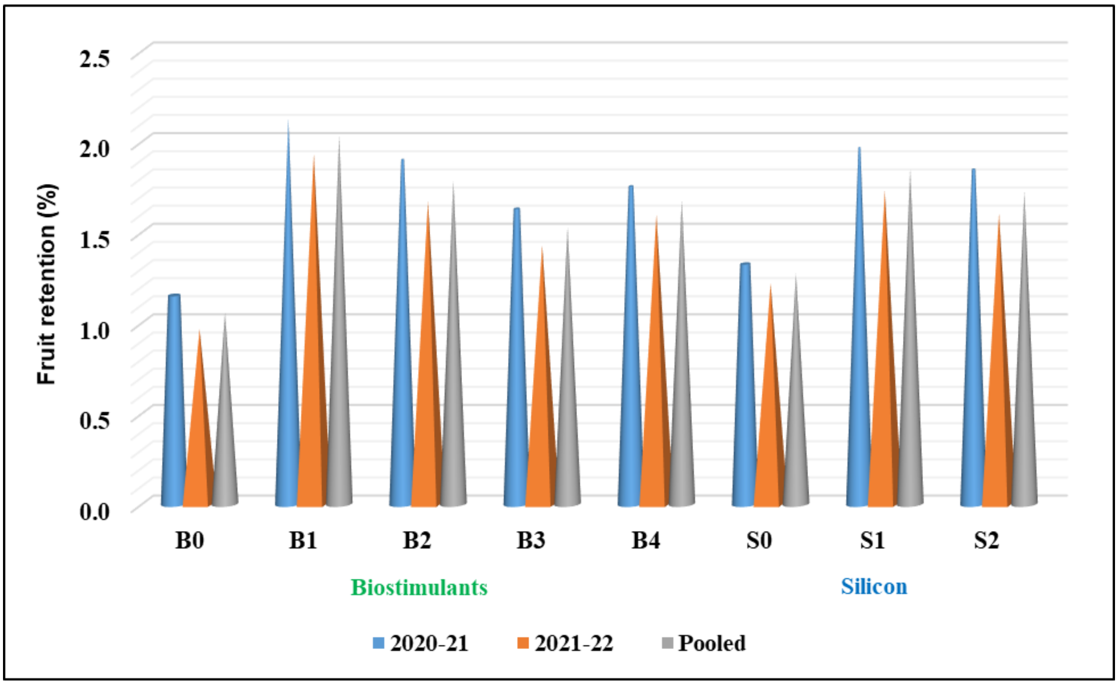

Fig. 1. Effect of biostimulants and silicon on fruit retention of mango cv. Kesar

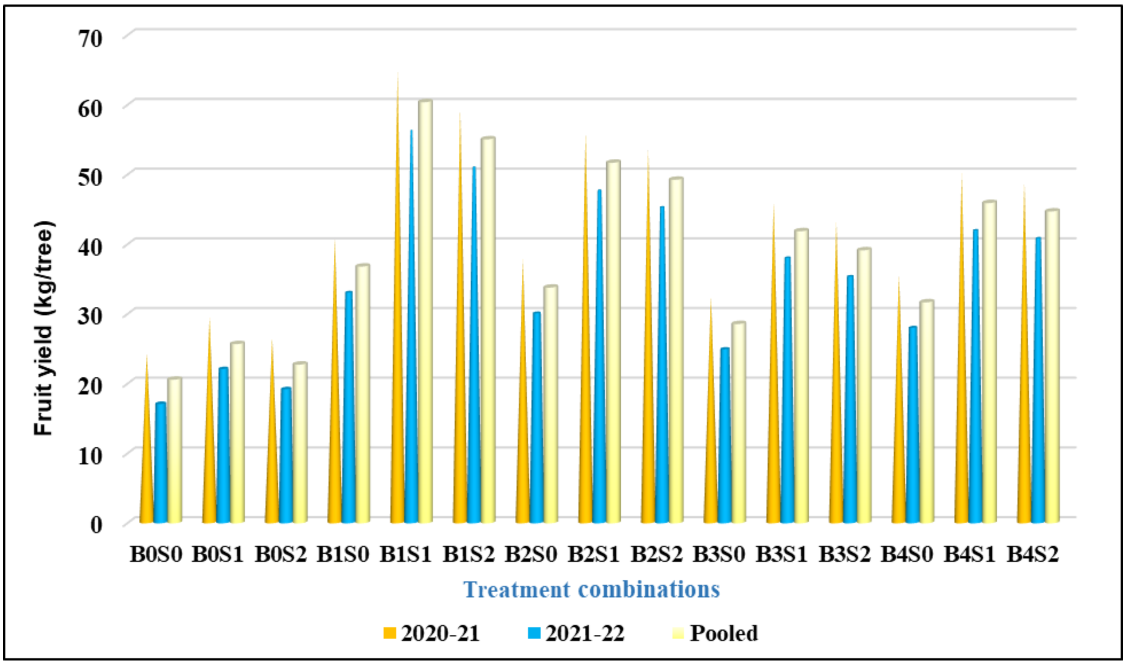

Fig. 2. Interaction effect of biostimulants and silicon on fruit yield of mango cv. Kesar

Table 1. Effect of biostimulants and silicon on number of nubbins per 100 fruits at pea and marble stage of mango cv. Kesar

Treatments	Number of nubbins per 100 fruits at pea stage			Number of nubbins per 100 fruits at marble stage		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Biostimulants (B)						
B_0 – Control (Without biostimulant)	30.90	33.73	32.31	20.00	22.70	21.35
B_1 – Humic acid (1.5 %)	19.52	21.31	20.42	9.78	11.57	10.67
B_2 – Panchagavya (3 %)	21.71	23.07	22.39	12.00	13.80	12.90
B_3 – Seaweed extract (0.2 %)	25.77	27.11	26.44	14.67	16.88	15.77
B_4 – Novel organic liquid fertilizer (2 %)	24.00	25.29	24.64	12.89	15.56	14.23
S.Em.±	1.00	1.01	0.71	0.73	0.83	0.56
C.D. at 5 %	2.89	2.91	2.01	2.13	2.42	1.57
Silicon (S)						
S_0 – Control (Without silicon)	28.35	30.04	29.19	17.07	19.75	18.41
S_1 – Potassium silicate (0.2 %)	21.57	23.47	22.52	11.73	13.87	12.80
S_2 – Orthosilicic acid (0.2 %)	23.22	24.79	24.00	12.80	14.68	13.74
S.Em.±	0.77	0.78	0.55	0.57	0.65	0.43
C.D. at 5 %	2.24	2.26	1.55	1.65	1.87	1.22
Interaction (B X S)						
S.Em.±	1.73	1.74	1.23	1.27	1.45	0.96
C.D. at 5 %	NS	NS	NS	NS	NS	NS
CV %	12.27	11.56	11.90	15.88	15.55	15.73
Year						
S.Em.±			0.45			0.35
C.D. at 5 %			1.27			1.00
Y X B						
S.Em.±			1.00			0.79
C.D. at 5 %			NS			NS
Y X S						
S.Em.±			0.78			0.61
C.D. at 5 %			NS			NS
Y X B X S						
S.Em.±			1.73			1.36
C.D. at 5 %			NS			NS

Table 2. Effect of biostimulants and silicon on fruit retention at harvesting and number of fruits per tree of mango cv. Kesar

Treatments	Fruit retention (%)			Number of fruits per tree		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Biostimulants (B)						
B_0 – Control (Without biostimulant)	1.15	0.96	1.06	143.61	104.23	123.92
B_1 – Humic acid (1.5 %)	2.13	1.93	2.03	236.34	191.09	213.71
B_2 – Panchagavya (3 %)	1.90	1.67	1.79	218.31	181.04	199.67
B_3 – Seaweed extract (0.2 %)	1.63	1.43	1.53	191.36	154.26	172.81
B_4 – Novel organic liquid fertilizer (2 %)	1.76	1.60	1.68	206.72	167.01	186.87
S.Em.±	0.07	0.06	0.04	3.08	2.75	2.06
C.D. at 5 %	0.19	0.17	0.13	8.91	7.98	5.85
Silicon (S)						
S_0 – Control (Without silicon)	1.33	1.22	1.27	175.31	134.12	154.71
S_1 – Potassium silicate (0.2 %)	1.97	1.73	1.85	215.17	175.87	195.52
S_2 – Orthosilicic acid (0.2 %)	1.85	1.60	1.73	207.33	168.59	187.96
S.Em.±	0.05	0.05	0.03	2.38	2.13	1.60
C.D. at 5 %	0.15	0.13	0.10	6.90	6.18	4.53
Interaction (B X S)						
S.Em.±	0.12	0.10	0.08	5.33	4.77	3.58
C.D. at 5 %	NS	NS	NS	15.43	13.82	10.13
CV %	11.64	11.58	11.63	4.63	5.18	4.88
Year						
S.Em.±			0.03			1.31
C.D. at 5 %			0.08			3.70
Y X B						
S.Em.±			0.06			2.92
C.D. at 5 %			NS			NS
Y X S						
S.Em.±			0.05			2.26
C.D. at 5 %			NS			NS
Y X B X S						
S.Em.±			0.11			5.06
C.D. at 5 %			NS			NS

Table 3. Effect of biostimulants and silicon on fruit yield of mango cv. Kesar

Treatments	**Fruit yield (kg/tree)**			**Fruit yield (t/ha)**		
	2020-21	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**
Biostimulants (B)						
B_0 – Control (Without biostimulant)	26.63	19.43	23.03	7.40	5.40	6.40
B_1 – Humic acid (1.5 %)	54.87	46.69	50.78	15.25	12.98	14.12
B_2 – Panchagavya (3 %)	48.96	40.93	44.95	13.61	11.38	12.50
B_3 – Seaweed extract (0.2 %)	40.40	32.70	36.55	11.23	9.09	10.16
B_4 – Novel organic liquid fertilizer (2 %)	44.73	36.87	40.80	12.43	10.25	11.34
S.Em.±	1.46	1.33	0.99	0.41	0.37	0.27
C.D. at 5 %	4.24	3.85	2.80	1.18	1.07	0.78
Silicon (S)						
S_0 – Control (Without silicon)	34.04	26.58	30.31	9.46	7.39	8.43
S_1 – Potassium silicate (0.2 %)	49.15	41.14	45.14	13.66	11.44	12.55
S_2 – Orthosilicic acid (0.2 %)	46.17	38.26	42.21	12.83	10.64	11.74
S.Em.±	1.13	1.03	0.77	0.32	0.29	0.21
C.D. at 5 %	3.28	2.99	2.17	0.91	0.83	0.60
Interaction (B X S)						
S.Em.±	2.53	2.30	1.71	0.70	0.64	0.48
C.D. at 5 %	7.34	6.68	4.85	2.04	1.86	1.35
CV %	10.18	11.30	10.70	10.18	11.30	10.70
Year						
S.Em.±			0.63			0.17
C.D. at 5 %			1.77			0.49
Y X B						
S.Em.±			1.40			0.39
C.D. at 5 %			NS			NS
Y X S						
S.Em.±			1.08			0.30
C.D. at 5 %			NS			NS
Y X B X S						
S.Em.±			2.42			0.67
C.D. at 5 %			NS			NS

Table 4. Interaction effect of biostimulants and silicon on number of fruits per tree and fruit yield of mango cv. Kesar

Treatment combinations	Number of fruits per tree			Fruit yield (kg/tree)			Fruit yield (t/ha)		
	2020-21	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**
$B_0 S_0$	133.50	98.97	116.24	24.16	17.06	20.61	6.72	4.74	5.73
$B_0 S_1$	154.66	113.35	134.01	29.37	22.07	25.72	8.16	6.13	7.15
$B_0 S_2$	142.67	100.35	121.51	26.37	19.18	22.77	7.33	5.33	6.33
$B_1 S_0$	202.58	158.49	180.54	40.69	32.99	36.84	11.31	9.17	10.24
$B_1 S_1$	259.26	211.88	235.57	64.66	56.18	60.42	17.97	15.62	16.80
$B_1 S_2$	247.17	202.90	225.03	59.28	50.90	55.09	16.48	14.15	15.31
$B_2 S_0$	191.53	148.15	169.84	37.62	30.02	33.82	10.46	8.35	9.40
$B_2 S_1$	235.16	201.07	218.12	55.88	47.59	51.73	15.53	13.23	14.38
$B_2 S_2$	228.23	193.89	211.06	53.39	45.19	49.29	14.84	12.56	13.70
$B_3 S_0$	167.56	125.27	146.41	32.29	24.89	28.59	8.98	6.92	7.95
$B_3 S_1$	208.58	171.56	190.07	45.85	37.95	41.90	12.75	10.55	11.65
$B_3 S_2$	197.96	165.94	181.95	43.07	35.27	39.17	11.97	9.80	10.89
$B_4 S_0$	181.39	139.70	160.54	35.45	27.95	31.70	9.86	7.77	8.81
$B_4 S_1$	218.19	181.46	199.83	50.00	41.89	45.95	13.90	11.65	12.77
$B_4 S_2$	220.59	179.86	200.23	48.73	40.76	44.74	13.55	11.33	12.44
S.Em. ±	5.33	4.77	3.58	2.53	2.30	1.71	0.70	0.64	0.48
C.D. at 5%	15.43	13.82	10.13	7.34	6.68	4.85	2.04	1.86	1.35
CV%	4.63	5.18	4.88	10.18	11.30	10.70	10.18	11.30	10.70

Table 5. Effect of biostimulants and silicon on fruit length and fruit breadth of mango cv. Kesar

Treatments	Fruit length (cm)			Fruit breadth (cm)		
	2020-21	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**
Biostimulants (B)						
B_0 – Control (Without biostimulant)	9.58	9.51	9.55	6.11	6.16	6.14
B_1 – Humic acid (1.5 %)	10.51	10.69	10.60	6.64	6.71	6.67
B_2 – Panchagavya (3 %)	10.34	10.46	10.40	6.57	6.52	6.54
B_3 – Seaweed extract (0.2 %)	9.93	10.04	9.99	6.37	6.39	6.38
B_4 – Novel organic liquid fertilizer (2 %)	10.17	10.27	10.22	6.46	6.45	6.46
S.Em.±	0.08	0.07	0.05	0.03	0.03	0.02
C.D. at 5 %	0.23	0.19	0.15	0.09	0.09	0.06
Silicon (S)						

Treatments	Fruit length (cm)			Fruit breadth (cm)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
S_0 – Control (Without silicon)	9.76	9.82	9.79	6.23	6.29	6.26
S_1 – Potassium silicate (0.2 %)	10.35	10.43	10.39	6.56	6.54	6.55
S_2 – Orthosilicic acid (0.2 %)	10.21	10.33	10.27	6.50	6.50	6.50
S.Em.±	0.06	0.05	0.04	0.02	0.02	0.02
C.D. at 5 %	0.18	0.15	0.11	0.07	0.07	0.05
Interaction (B X S)						
S.Em.±	0.14	0.11	0.09	0.05	0.06	0.04
C.D. at 5 %	0.41	0.33	0.26	0.15	0.16	0.11
CV %	2.40	1.93	2.18	1.38	1.50	1.44
Year						
S.Em.±			0.03			0.01
C.D. at 5 %			NS			NS
Y X B						
S.Em.±			0.07			0.03
C.D. at 5 %			NS			NS
Y X S						
S.Em.±			0.06			0.02
C.D. at 5 %			NS			NS
Y X B X S						
S.Em.±			0.13			0.05
C.D. at 5 %			NS			NS

Table 6. Interaction effect of biostimulants and silicon on fruit length and fruit breadth of mango cv. Kesar

Treatment combinations	Fruit length (cm)			Fruit breadth (cm)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
$B_0 S_0$	9.54	9.19	9.36	5.99	6.07	6.03
$B_0 S_1$	9.61	9.68	9.65	6.19	6.24	6.21
$B_0 S_2$	9.60	9.67	9.63	6.15	6.18	6.16
$B_1 S_0$	9.86	10.06	9.96	6.34	6.39	6.36
$B_1 S_1$	10.93	11.20	11.06	6.82	6.90	6.86
$B_1 S_2$	10.73	10.82	10.78	6.77	6.83	6.80
$B_2 S_0$	9.84	10.02	9.93	6.32	6.35	6.34
$B_2 S_1$	10.67	10.72	10.69	6.72	6.61	6.66

Treatment combinations	Fruit length (cm)			Fruit breadth (cm)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
$B_2 S_2$	10.52	10.64	10.58	6.67	6.58	6.63
$B_3 S_0$	9.75	9.88	9.82	6.23	6.31	6.27
$B_3 S_1$	10.12	10.12	10.12	6.53	6.44	6.49
$B_3 S_2$	9.93	10.12	10.02	6.34	6.42	6.38
$B_4 S_0$	9.81	9.97	9.89	6.29	6.34	6.31
$B_4 S_1$	10.44	10.43	10.43	6.55	6.52	6.54
$B_4 S_2$	10.25	10.41	10.33	6.55	6.50	6.52
S.Em. ±	0.14	0.11	0.09	0.05	0.06	0.04
C.D. at 5%	0.41	0.33	0.26	0.15	0.16	0.11
CV%	2.40	1.93	2.18	1.38	1.50	1.44

Table 7. Effect of biostimulants and silicon on fruit weight, pulp weight and peel weight of mango cv. Kesar

Treatments	Fruit weight (g)			Pulp weight (g)			Peel weight (g)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Biostimulants (B)									
B_0 – Control (Without biostimulant)	185.83	185.30	185.56	134.96	134.80	134.88	21.75	21.72	21.74
B_1 – Humic acid (1.5 %)	229.68	239.48	234.58	172.23	179.50	175.87	24.31	25.36	24.84
B_2 – Panchagavya (3 %)	221.94	222.10	222.02	165.60	165.52	165.56	23.88	23.95	23.92
B_3 – Seaweed extract (0.2 %)	209.91	209.44	209.67	154.84	154.41	154.63	23.25	23.24	23.24
B_4 – Novel organic liquid fertilizer (2 %)	215.40	218.24	216.82	159.38	161.40	160.39	23.50	23.84	23.67
S.Em.±	3.07	2.61	2.02	2.58	2.24	1.71	0.53	0.57	0.39
C.D. at 5 %	8.91	7.55	5.71	7.46	6.48	4.83	1.53	1.65	1.10
Silicon (S)									
S_0 – Control (Without silicon)	193.53	195.34	194.43	141.32	142.58	141.95	22.27	22.50	22.38
S_1 – Potassium silicate (0.2 %)	224.62	227.86	226.24	167.57	170.02	168.79	24.02	24.39	24.21
S_2 – Orthosilicic acid (0.2 %)	219.50	221.53	220.52	163.33	164.78	164.06	23.73	23.98	23.85
S.Em.±	2.38	2.02	1.56	2.00	1.73	1.32	0.41	0.44	0.30
C.D. at 5 %	6.90	5.85	4.42	5.78	5.02	3.74	1.18	1.28	0.85
Interaction (B X S)									
S.Em.±	5.33	4.52	3.49	4.46	3.88	2.96	0.91	0.99	0.67
C.D. at 5 %	15.43	13.08	9.89	12.93	11.23	8.37	NS	NS	NS
CV %	4.34	3.64	4.00	4.91	4.22	4.57	6.77	7.23	7.01
Year									

Treatments	Fruit weight (g)			Pulp weight (g)			Peel weight (g)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
S.Em.±			1.27			1.08			0.25
C.D. at 5 %			NS			NS			NS
Y X B									
S.Em.±			2.85			2.41			0.55
C.D. at 5 %			NS			NS			NS
Y X S									
S.Em.±			2.21			1.87			0.42
C.D. at 5 %			NS			NS			NS
Y X B X S									
S.Em.±			4.94			4.18			0.95
C.D. at 5 %			NS			NS			NS

Table 8. Interaction effect of biostimulants and silicon on fruit weight and pulp weight of mango cv. Kesar

Treatment combinations	Fruit weight (g)			Pulp weight (g)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
$B_0 S_0$	181.52	171.32	176.42	130.92	123.98	127.45
$B_0 S_1$	190.64	194.45	192.54	139.39	142.45	140.92
$B_0 S_2$	185.33	190.13	187.73	134.57	137.97	136.27
$B_1 S_0$	202.03	207.78	204.90	148.92	152.95	150.93
$B_1 S_1$	247.78	261.63	254.71	187.39	197.83	192.61
$B_1 S_2$	239.23	249.01	244.12	180.39	187.72	184.06
$B_2 S_0$	196.12	200.92	198.52	143.82	146.88	145.35
$B_2 S_1$	236.46	234.29	235.37	177.27	175.60	176.43
$B_2 S_2$	233.24	231.10	232.17	175.72	174.07	174.90
$B_3 S_0$	192.15	197.02	194.59	140.19	143.66	141.93
$B_3 S_1$	219.07	218.92	218.99	162.61	162.45	162.53
$B_3 S_2$	218.50	212.37	215.43	161.73	157.12	159.43
$B_4 S_0$	195.83	199.64	197.73	142.72	145.42	144.07
$B_4 S_1$	229.15	230.02	229.58	171.17	171.77	171.47
$B_4 S_2$	221.23	225.06	223.14	164.24	167.03	165.64
S.Em. ±	5.33	4.52	3.49	4.46	3.88	2.96
C.D. at 5%	15.43	13.08	9.89	12.93	11.23	8.37
CV%	4.34	3.64	4.00	4.91	4.22	4.57

Table 9. Effect of biostimulants and silicon on stone weight and pulp: stone ratio of mango cv. Kesar

Treatments	Stone weight (g)			Pulp: stone ratio		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Biostimulants (B)						
B_0 – Control (Without biostimulant)	29.19	29.13	29.16	4.63	4.63	4.63
B_1 – Humic acid (1.5 %)	33.38	34.82	34.10	5.16	5.15	5.16
B_2 – Panchagavya (3 %)	32.82	32.89	32.86	5.05	5.04	5.05
B_3 – Seaweed extract (0.2 %)	31.68	31.65	31.66	4.89	4.88	4.89
B_4 – Novel organic liquid fertilizer (2 %)	32.14	32.59	32.36	4.96	4.96	4.96
S.Em.±	0.67	0.71	0.49	0.11	0.11	0.08
C.D. at 5 %	1.95	2.05	1.38	0.33	0.33	0.23
Silicon (S)						
S_0 – Control (Without silicon)	30.01	30.31	30.16	4.72	4.71	4.71
S_1 – Potassium silicate (0.2 %)	33.04	33.53	33.29	5.07	5.07	5.07
S_2 – Orthosilicic acid (0.2 %)	32.48	32.80	32.64	5.02	5.02	5.02
S.Em.±	0.52	0.55	0.38	0.09	0.09	0.06
C.D. at 5 %	1.51	1.59	1.07	0.26	0.25	0.18
Interaction (B X S)						
S.Em.±	1.16	1.23	0.85	0.20	0.20	0.14
C.D. at 5 %	NS	NS	NS	NS	NS	NS
CV %	6.33	6.59	6.46	6.97	6.87	6.92
Year						
S.Em.±			0.31			0.05
C.D. at 5 %			NS			NS
Y X B						
S.Em.±			0.69			0.11
C.D. at 5 %			NS			NS
Y X S						
S.Em.±			0.53			0.09
C.D. at 5 %			NS			NS
Y X B X S						
S.Em.±			1.20			0.20
C.D. at 5 %			NS			NS

4. CONCLUSION

The result obtained from research experiment, it can be concluded that the foliar application of humic acid 1.5 % along with potassium silicate 0.2 % at the time of initiation of flowering, pea and marble stage improved yield and yield attributing characters of mango cv. Kesar.

5. FUTURE SCOPE

The use of biostimulants and silicon in mango cultivation plays a pivotal role in enhancing yields, elevating fruit quality, minimizing fruit drop and bolstering fruit retention. Given mango's global significance, ongoing research is indispensable for advancing agricultural practices. Future studies can focus on tailoring treatments and dosages to specific regions, standardizing application methods, exploring combined effects on various parameters like yield and disease resistance and assessing environmental and economic impacts. Disseminating findings to farmers and ensuring collaboration with local institutions are vital for widespread adoption and sustainable mango cultivation. Through comprehensive research and collaborative efforts, the agricultural community can continuously refine mango cultivation practices, ensuring food security and environmental sustainability.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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