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Assessment of fruit morphology, bioactive compounds and yield potential by the application of calcium chloride and chitosan inmango cv. Mallika

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ABSTRACT

This experiment was conducted in the experimental area of BAU Sabour, Bhagalpur, Bihar, in the year 2021-22 to see the effect of calcium chloride (1.5% and 3.0%) and chitosan (0.5% and 1.0%) alone and their combinations on the yield and bioactive compounds of mango (Mangifera indica L.) cv. Mallika. These chemicals were sprayed on the 15th and 30th days before harvesting. These chemicals were choosen to enhance the quality and shelf-life of mango for longer duration availability to consumers. The results of the study clearly showed that fruit morphology, such as fruit length, breadth, volume, and weight (155 mm, 95 mm, 532 ml, 561.53 g), were recorded at maximum with T_8: $CaCl_2$ 3% + chitosan 1%. It was also found that this treatment had the highest yield (28.33 fruits/plant). Minimum peel percent (14.30) was observed in T_6: $CaCl_2$ 21.5% + chitosan 1%, whereas minimum stone percent (8.99) and maximum pulp percent (76.86) were in T_8: $CaCl_2$ 3% + chitosan 1%. Highest TSS, TSS: acid ratio, total sugar, reducing sugar, and ascorbic acid (13.46 °Brix, 21.36, 3.79%, 1.78%, and 60.86 mg/100g pulp, respectively) were also in T_8, while phenol, anthocyanin, and antioxidant content (49.36 mg GAE/g pulp, 0.82 mg/100g peel, and 1.28 µmol Trolox equivalent/g pulp) were in T_7: $CaCl_2$ 3% + chitosan 0.5%.

Keywords: *Mango, Mallika, chitosan, CaCl2, fruit morphology, bioactive compounds, antioxidant, phenol, anthocyanin, yield*

INTRODUCTION

Mango (*Mangifera indica* L.) is consistently considered the choicest tropical fruit in the world. It is the national fruit of India and known as the king of the fruits. India is the largest producer of mango in the world. India contributes about 64 percent of mangoes around the globe. The total production of mango in India is estimated to be 19 million metric tons in 2021 [1]. Mango is known for its vibrant colour, delicious taste, exotic flavour, highly rich nutritional properties, and enticing aroma. Among the different cultivars recommended for cultivation under the agro-climatic conditions of Bihar, Mallika is an important and popular cultivar that is widely grown due to its high yield and excellent quality. Mallika trees are semi-vigorous to vigorous and regular bearers in nature. The fruit is large, ovate-oblong, and pulp is golden yellow and fibreless. The colour of the peel is apricot yellow, and the seed is thin.

Foliar application is an essential tool for the sustainable and productive management of fruit crops. Foliar spray is a way to reduce the use of chemical fertilizers and their environmental hazards [21]. Besides, by foliar feeding, nutrients can be delivered directly and quickly to the plants, if needed. Some of the plant organs, like fruits, need nutrients such as calcium more than whole plants when the roots are still unable to absorb nutrients due to low soil temperature [10]. In this sense, pre-harvest application of calcium may delay senescence in fruits with no detrimental effect on consumer acceptance. Calcium is a key plant nutrient that has a significant role in cell functions, which reduces softening and senescence of fruits [2], and it is also considered the most important mineral element determining fruit quality [9]. Exogenously applied calcium stabilizes the plant cell wall and protects it from cell wall-degrading enzymes [35], resulting in improved quality of various fruit crops, including mango. Romero et al. [26] found that the application of calcium as a pre-harvest spray increased the fruit quality of mango.

As far as chitosan is concerned, chitosan is a high molecular weight cationic polysaccharide derived from chitin [37] that happens to be nontoxic, biocompatible, bio functional, and biodegradable [28]. Pre-harvest spraying with chitosan is highly feasible and has a beneficial effect on fruit quality attributes [25]. Previous studies showed that using chitosan pre-harvesting was very effective in enhancing growth, yield, and fruit quality parameters in different fruit crop species. [8,13,22]. Thus, the present study aims to assess the impact of exogenously applied calcium chloride and chitosan on yield, fruit morphology, and different bioactive ingredients such as TSS, titratable acidity, ascorbic acid, total and reducing sugars, phenols, antioxidants, etc. on mango cv. Mallika.

MATERIALSAND METHODS

The present investigation was conducted in the Horticulture Garden of Bihar Agricultural College, Sabour, Bhagalpur, which is situated at a longitude of 87°2' 42" East and latitude of 25° 15' 40" North at an altitude of 46 meters above mean sea. All the plants were selected for uniform growth and size, which were planted in 2.5 x 3 m spacing. The age of the mango plant is 12 years, which were maintained under a uniform cultural schedule during investigation. The pre-harvest foliar spray was given as a chemical and was sprayed on 15 and 30 days before the harvest date in 2020-21. The experiment was conducted in a randomized block design with three replications with nine

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treatments. The treatments were comprised of T_1- $CaCl_2$ 1.5%, T_2 - $CaCl_2$ 3%, T_3 - chitosan 0.5%, T_4 - chitosan 1%, T_5 - $CaCl_2$ 1.5 % + chitosan 0.5%, T_6 - $CaCl_2$ 1.5% + chitosan 1%, T_7 - $CaCl_2$ 3% + chitosan 0.5%, T_8 - $CaCl_2$ 3% + chitosan 1% and T_9 - control (water spray).

Observations were recorded on yield (number of fruits per plant), physical parameters (fruit length, breadth, weight, peel %, stone %, and pulp %), and biochemical parameters (TSS, titratable acidity, TSS:acid ratio, reducing sugar, total sugar, ascorbic acid, antioxidant activity, phenolic content, and anthocyanin content). Three fruits / treatments / replications were taken for quality analysis. Yield (number of fruits per plant) was recorded from individual trees, and the total number of marketable fruits per tree per replication under each treatment was counted manually. Physical parameters (fruit length and breadth) were recorded with the help of a vernier caliper, which was expressed in cm, while fruit weight was recorded with the help of a pan balance, which was expressed in g, and peel, stone, and pulp (%) were expressed by this formula:

$$\text{Weight of peel Percentage of peel} = \frac{\text{Weight of fruit}}{\text{Weight of fruit}} \times 100$$

$$\text{Weight of stone Percentage of stone} = \frac{\text{Weight of fruit}}{\text{Weight of fruit}} \times 100$$

$$\text{Weight of pulp Percentage of pulp} = \frac{\text{Weight of fruit}}{\text{Weight of fruit}} \times 100$$

Biochemical parameters such as TSS were recorded by an Erma hand refractometer. Titratable acidity was determined according to [12]. Reducing sugar and total sugar were determined by the [16] method. The ascorbic acid content in the fruit was estimated by [14]. Antioxidant activity was performed according to the method of [1]. Phenolic content was determined by the method of [34]. Anthocyanin content was determined by the method suggested by [23]. The mean and standard deviation were computed, and one-way analysis of variance (ANOVA) was used to assess tabulated data, and statistical differences between means were estimated using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

The data recorded that the highest yield (28.33 number of fruits per tree) was found in T_8 - $CaCl_2$ 3% + chitosan 1%. The significant increase in fruit yield might be an accumulative effect of an increase in several fruits due to a reduction in fruit drop and higher fruit weight by the direct and indirect effect of foliar spray of calcium. In addition, it might be due to the promotion of starch formation followed by the rapid transportation of carbohydrates in calcium-treated plants. These results are in agreement with the earlier finding of [30, 31] in mango. The effectiveness of chitosan on yield and its components might be because chitosan has a simulative effect on physiological processes and improves the transportation of nitrogen in the functional leaves, which improves vegetative growth and development [7, 11]. Physical parameters such as fruit length, breadth, and weight (15.5 cm, 9.5 cm, and 561.53 g) were recorded and enhanced when sprayed with T_8 - $CaCl_2$ 3% + chitosan 1% (Table 1). This might be due to the application of calcium, which attributed to more Ca in fruits and increased the fruit size in length and breadth by increasing the cell density in the cortex area of fruit, as reported by [29], while appreciable improvement in fruit weight by calcium chloride application is due to more growth of fruits by accelerated rates of cell enlargement and cell division and larger intercellular space. It might also affect in influence the formation and changes of carbohydrates and carbohydrate enzymes due to enhanced absorption of water and mobilization of sugar in expanded cells and increased volume of intercellular space in the pulp as reported by [27]. The beneficial effect of chitosan may be interpreted as its role in achieving a good balance between vegetative growth and fruitingthrough nutrient availability, which is reflected in its turn on increasing the accumulation of total carbohydrate content in fruit [17, 6]. The recorded data presented in (Table 2) revealed that physical parameters such as peel percent, stone percent, and pulp percent were minimum in T_6 - $CaCl_2$ 1.5% + chitosan 1% while minimum stone percent (8.99) and maximum pulp percent (76.86) were in T_8: $CaCl_2$ 3% + Chitosan 1% while minimum stone per cent (8.99) and maximum pulp per cent (76.86) was in T_8- $CaCl_2$ 3% + Chitosan 1%. The increase in fruit pulp is due to more accumulation of photosynthates in the matured fruits by the beneficial effect of calcium. The increase in fruit pulp is due to more accumulation of photosynthates in the matured fruits by the beneficial effect of calcium. These findings were collaborated with [4, 5, 15].

The scrutiny of data regarding biochemical parameters such as maximum TSS, minimum acidity, and highest TSS:acid ratio (13.46 °Brix, 0.604%, and 21.36, respectively) was in treatment T_8: $CaCl_2$ 3% + chitosan 1% (Table 3). The increase in TSS due to the application of calcium is due to the function of the number of enzymes that might have stimulated the physiological processes in terms of hydrolysed starch and polysaccharides. Metabolic activity during the change of available starch and organic acid into soluble sugars and enhanced solubilisation of insoluble starch and protein present in the cell wall and middle lamella, thus TSS might have been increased. [33] on mango found similar results concerning TSS. Decrease in acidity might be due to the involvement of growth substances at the metabolic level in regulating vital physiological and biochemical processes seems to have decreased total acidity in fruits. [20] on strawberry and [18] on table grape found similar results.

The recorded data (Table 4) revealed that biochemical parameters such as ascorbic acid, total sugar, and reducing sugar (60.86 mg/100g pulp, 3.79%, and 1.78%, respectively) were found to be maximum with T_8: $CaCl_2$ 3% + chitosan 1%. The increase in ascorbic acid content might be due to continued synthesis of glucose-6-phosphate through the growth and development of fruits, which is thought to be a precursor of vitamin C [3] in mango, found similar results. Higher ascorbic acid content in $CaCl_2$-treated fruits could be related to inhibiting the action of calcium on the activity of ascorbic acid oxidase that uses ascorbate as a substrate [32]. The perceptible increase in sugar content in fruits by foliar spray of calcium, chitosan, and their combinations might be due to rapid translocation of more sugar in fruits due to rapid transformation of starch into sugar in the presence of an enzyme by application of calcium. In addition, chitosan may enhance growth and development by some signalling pathway-related to auxin biosynthesis via a tryptophan-independent pathway. This finding is in conformity with [19] on mango fruits concerning total sugar.

Phenol, anthocyanin, and antioxidant content (49.36 mg GAE/gm pulp, 0.82 mg/100g peel, and 1.28 mol Trolox equivalent/g pulp, respectively) were found highest in T_7: $CaCl_2$ 3% + chitosan 0.5% (Table 5).

The increase in antioxidant activity was associated with a lower content of dehydroascorbic acid. This finding corroborates the report of [36] on strawberry. Calcium-treated fruits have been found to enhance the colour formation of mango fruit peels by affecting phenylalanine ammonia-lyase and tyrosine ammonia-lyase activities, thus justifying partly the higher anthocyanin content of fruit peels deriving from the plant treated with calcium. [24] reported that calcium increases the amount of total phenol in apple fruit. They suggested that since calcium increases polysaccharide content in fruit cell walls and the permeability of membranes, therefore cell wall strength and cell membrane can be maintained, which leads to preventing the oxidation of phenolic compounds. Thus, phenolic content may be increased.

CONCLUSION

Findings of present study revealed that the application of $CaCl_2$ 3% + chitosan 1% was most effective for yield-related characters like total number of fruits per plant, fruit weight, fruit volume, fruit length, breadth, and pulp per-cent. $CaCl_2$ 3% + chitosan 1% were found effective for improving fruit quality characteristics like increased TSS, ascorbic acid, total sugar and reducing sugar while decreased in titratable acidity. It was also reported that $CaCl_2$ 3% + chitosan 0.5% were effective for increasing anthocyanin content in peel, antioxidant and phenol.

FUTURE SCOPE OF THE EXPERIMENT

The study provides a solid foundation for future research and development.

By using these two formulations, they could be used to enhance the yield potential and quality parameters of mango. These two concentrations work as a promising alternative as environmentally friendly compounds. Several other concentrations and new formulations within focusing organic nature of fruit may be tested for further experimental research.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest: The authors declare that they have no conflict of interest.

AUTHOR'S CONTRIBUTION

Nishant: Main investigator: methodology: writing-original draft. Kumari Karuna: Data curation; methodology; writing-original draft. Ruby Rani: Conceptualization; supervision. Abhay Mankar: Conceptualization; resources; writing-original draft.

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Table 1. Effect of pre-harvest spray of calcium chloride and chitosan on yield and fruit morphology of mango cv. Mallika

S.No.	Treatments	Yield (No. of fruits/plant)	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (gm)
1.	T1 : CaCl2 1.5%	24.00^{bcde}	13.50^{abcd}	8.20^{c}	459.20^{bc}
2.	T2 : CaCl2 3.0%	24.33^{bcde}	13.97^{abcd}	8.30^{c}	470.26^{bc}
3.	T3 : Chitosan 0.5%	22.00^{de}	12.67^{cd}	7.93^{cd}	433.93^{bc}
4.	T4 : Chitosan1.0%	23.33^{cde}	13.13^{bcd}	8.13^{c}	458.67^{bc}
5.	T5 : CaCl2 1.5% + Chitosan 0.5%	25.67^{abcd}	14.13^{abcd}	8.40^{bc}	511.33^{bc}
6.	T6 : CaCl2 1.5% + Chitosan1.0%	26.67^{abc}	14.37^{abc}	8.43^{bc}	554.76^{abc}
7.	T7 : CaCl2 3.0% + Chitosan 0.5%	27.67^{ab}	15.00^{ab}	9.10^{ab}	582.96^{ab}
8.	T8 : CaCl2 3.0% + Chitosan 1.0%	28.33^{a}	15.50^{a}	9.50^{a}	561.53^{a}
9.	T9 :Water spray	21.00^{e}	12.27^{d}	7.37^{d}	422.46^{c}
	SEM(±)	1.19	6.10	2.42	46.21
	CV	8.32	7.64	4.63	15.81

Table 2. Effect of pre-harvest spray of calcium chloride and chitosan on fruit morphology of mango cv. Mallika

S.No.	Treatments	Peel (%)	Stone (%)	Pulp (%)
1.	T1 : CaCl2 1.5%	16.14^{b}	10.15^{c}	75.46^{c}
2.	T2 : CaCl2 3.0%	16.30^{a}	10.62^{b}	72.77^{g}
3.	T3 : Chitosan 0.5%	15.07^{d}	9.72^{de}	73.87^{e}
4.	T4 : Chitosan1.0%	15.46^{c}	9.53^{f}	74.88^{d}
5.	T5 : CaCl2 1.5% + Chitosan 0.5%	15.13^{d}	10.94^{a}	76.25^{b}
6.	T6 : CaCl2 1.5% + Chitosan1.0%	14.30^{f}	9.68^{e}	73.02^{f}
7.	T7 : CaCl2 3.0% + Chitosan 0.5%	15.10^{d}	9.83^{d}	76.39^{a}
8.	T8 : CaCl2 3.0% + Chitosan 1.0%	14.48^{e}	8.99^{h}	76.86^{a}
9.	T9 : Water spray	15.03^{d}	9.34^{g}	71.79^{g}
	SEM(±)	1.68	1.09	6.34
	CV	19.19	19.20	14.70

Table 3. Effect of pre-harvest spray of calcium chloride and chitosanon bioactive compounds of mango cv. Mallika

S. No.	Treatments	TSS (°Brix)	Titratable acidity(%)	TSS:acid ratio
1.	T1 : CaCl2 1.5%	11.86^{bcd}	0.903^{d}	13.14^{f}
2.	T2 : CaCl2 3.0%	11.96^{bcd}	0.843^{e}	14.19^{e}
3.	T3 : Chitosan 0.5%	11.17^{d}	1.023^{b}	10.04^{h}
4.	T4 : Chitosan1.0%	11.25^{cd}	0.964^{c}	11.58^{g}
5.	T5 : CaCl2 1.5% + Chitosan 0.5%	12.06^{bc}	0.783^{f}	15.41^{d}
6.	T6 : CaCl2 1.5% + Chitosan1.0%	12.23^{b}	0.724^{g}	16.89^{c}
7.	T7 : CaCl2 3.0% + Chitosan 0.5%	12.40^{b}	0.664^{h}	18.67^{b}
8.	T8 : CaCl2 3.0% + Chitosan 1.0%	14.46^{a}	0.604^{h}	21.36^{a}
9.	T9 :Water spray	10.01^{e}	1.084^{a}	09.23^{h}
	SEM(±)	0.25	0.01	0.32
	CV	3.72	0.12	3.93

Table 4. Effect of pre-harvest spray of calcium chloride and chitosan on bioactive compounds of mango cv. Mallika

S. No.	Treatments	Ascorbic acid (mg/100g pulp)	Total sugar (%)	Reducing Sugar (%)
1.	T1 : CaCl2 1.5%	55.19^{f}	3.12^{d}	1.62^{e}
2.	T2 : CaCl2 3.0%	56.56^{e}	3.16^{cd}	1.63^{de}
3.	T3 : Chitosan 0.5%	52.85^{h}	2.95^{e}	1.54^{fg}
4.	T4 : Chitosan1.0%	54.15^{g}	2.97^{e}	1.58^{ef}
5.	T5 : CaCl2 1.5% + Chitosan 0.5%	57.83^{d}	3.19^{cd}	1.68^{cd}
6.	T6 : CaCl2 1.5% + Chitosan1.0%	58.75^{c}	3.21^{c}	1.70^{bc}
7.	T7 : CaCl2 3.0% + Chitosan 0.5%	59.27^{b}	3.38^{b}	1.75^{ab}
8.	T8 : CaCl2 3.0% + Chitosan 1.0%	60.86^{a}	3.79^{a}	1.78^{a}
9.	T9 : Water spray	51.54^{i}	2.72^{f}	1.49^{g}
	SEM(±)	0.01	0.02	0.01
	CV	0.04	1.26	0.98

Table 5. Effect of pre-harvest spray of calcium chloride and chitosan on antioxidant, phenol and anthocyanin content of mango cv. Mallika

S.No.	Treatments	Antioxidant (µmol TE/g pulp)	Phenol (mg GAE /g pulp)	Anthocyanin (mg /100g peel)
1.	T1 : CaCl2 1.5%	1.21^{bcd}	45.37^{h}	0.76^{bcd}
2.	T2 : CaCl2 3.0%	1.23^{abcd}	45.77^{g}	0.77^{abcd}
3.	T3 : Chitosan 0.5%	1.18^{cd}	46.51^{f}	0.73^{cd}
4.	T4 : Chitosan1.0%	1.19^{bcd}	46.88^{e}	0.75^{bcd}
5.	T5 : CaCl2 1.5% + Chitosan 0.5%	1.24^{abc}	47.66^{d}	0.79^{abc}
6.	T6 : CaCl2 1.5% + Chitosan1.0%	1.25^{ab}	48.35^{c}	0.80^{ab}
7.	T7 : CaCl2 3.0% + Chitosan 0.5%	1.28^{a}	49.36^{a}	0.82^{a}
8.	T8 : CaCl2 3.0% + Chitosan 1.0%	1.27^{a}	48.90^{b}	0.81^{ab}
9.	T9 : Water spray	1.16^{d}	44.73^{i}	0.72^{d}
	SEM(±)	0.01	0.02	0.01
	CV	0.32	0.02	0.28

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