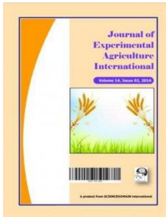

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Effect of Plant Growth Regulators and Packaging on Flowering, Fruit Quality and Shelf Life in Mango cv. Amrapali

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Authors' contributions

This work was carried out in collaboration between all authors. Author SN designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors AS and CSM managed the analyses of the study. Author CSM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To study the influence of plant growth regulators on flowering, yield, shelf life and its combined effect with packaging on quality and shelf life.
Study Design: Factorial Randomized Block Design
Place and Duration of Study: Horticulture Experimental Farm, School of Agricultural Sciences and Rural Development, Medziphema Campus, Nagaland University, Medziphema during 2006-2008.
Methodology: Pre-harvest treatments comprised of foliar spray of growth regulator naphthalene acetic acid (NAA) @ 100ppm and soil drenching Paclobutrazol (PBZ) @ 5ml/L/tree along the drip zone prior to bud differentiation in the month of September and a control (no treatment) on the mango tree. Fruits of uniform size without injury or decay were harvested from tagged trees and transported immediately to laboratory for the post-harvest experiments (polyethylene packing and control).

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Results: PBZ treatment greatly influenced flowering, yield and fruit quality attributes and induced early flowering (79 days), higher flowering shoots (85.77 %), number of fruitlets per panicle (5.56), number of fruits per panicle at harvesting stage (2.23), number of fruits per tree (44.52) and fruit yield (8.62 kg per tree). TSS (11.93°Brix), TSS: Acid ratio (16.54), total sugar (8.43 %) and ascorbic acid content (47.03 mg/100g pulp) of mango fruit were also influenced by PBZ treatment. In contrast, NAA treatment showed higher fruit weight, fruit size, pulp weight and pulp: stone ratio. The post-harvest treatments consist of packing the fruits with polyethylene material of 0.3 mm thickness and 32 x 25 cm size and control. The pre- and post-harvest treatments had significant influence on the physiological loss in weight (PLW), appearance, sensory quality, firmness, total sugar, reducing sugar and non-reducing sugar of the fruit during storage. Shelf life was significantly influenced by pre- and post-harvest treatments. Shelf life was recorded more in PBZ treatment (15.33 days) closely followed by NAA treatment (15 days) where the influence reached the level of significance. Further analysis revealed that fruits from polyethylene packing showed the significantly better result with 14.89 days of shelf life as compared to control with only 13.33 days.

Conclusion: Both PBZ @ 5 ml and NAA @ 100 ppm are effective as pre-harvest treatment for enhancing the floral characters, yield and its attributes as well as physicochemical characteristics of fruits. Polyethylene packed fruits had lower PLW, better appearance and firmness, higher ascorbic acid and shelf life.

Keywords: Mango; NAA; PBZ; packaging; yield and quality.

1. INTRODUCTION

Mango (*Mangifera indica* Linn), is the most important fruit of India and is known as the 'King of Fruits', and is one of the choicest fruit of our country belonging to the family Anacardiaceae. Amrapali is considered to be the best cultivar after Alphonso. However being perishable in nature, it requires proper care for its longer storage and transportation. India occupies the top position among mango growing countries of the world and produces 40.48% of the total world production. The total export of mangoes from India is 59.22 thousand tons, valuing rupees 162.92 crores during 2010-2011 [1]. The post-harvest management and infrastructure facilities available in our country are one of the major constraints, which hamper the export of mangoes. The storage life of mango fruit is not more than 8 – 10 days at room temperature and thus the perishability nature of the fruits poses a great problem. The purpose of obtaining maximum profit will not be served unless this increased production is supplemented with similar efforts to minimize their post-harvest losses, which range between 25 – 30% [2]. Shelf-life of fruits and vegetables can be improved by pre-harvest application of various chemicals [3]. Use of Plant Bio Regulators such as auxins, gibberellins, cytokinins, abscisic acid and paclobutrazol as pre-harvest sprays can increase the shelf life of the fruit and also improve its growth parameters. Quality of the fruit can also be enhanced. Paclobutrazol, a broad spectrum growth retardant and an inhibitor of GA_3 synthesis, has been found to be effective to control the alternate bearing in mango [4]. In recent years, use of paclobutrazol for mango has increased tremendously in the country. Plastic packaging help in minimising the cost of packaging and makes the whole process less dependent on scarce material like wood and other natural resources. In nutshell, plastics are helpful in maintaining the freshness and retaining the quality of fruits for longer duration. The ability of plastics to create modified micro-environment (CO_2, O_2, humidity) around the packed produces gives a unique place in the packaging industry and plastics helps in maintaining freshness and retaining quality of fruits for longer duration.

2. MATERIALS AND METHODS

The study was carried out at the Horticulture Experimental Farm, School of Agricultural Sciences and Rural Development, Medziphema Campus, Nagaland University, Medziphema during 2006-2008 on 10 year old uniformly growth and disease free mango tree of cv. Amrapali. Fruits of uniform size without injury or decay were harvested from tagged trees and transported immediately to laboratory for the post-harvest experiments. The experiment was laid out in Factorial Randomized Block Design with three replications. The growth regulator treatments included Control (P_1), NAA @ 100 ppm by foliar application (P_2) and Paclobutrazol (PBZ) @ 5 ml/L/tree (P_3) soil drenching prior to bud differentiation in the month of September.

The fruits were harvested from the field and then packed with Polyethylene material of 0.3 mm thickness and 32 x 25 cm size and analysed in the laboratory for further observations at five days interval till until the end of shelf life. The data recorded during the period of investigation were computed, analysed and inferred for significant test in accordance with the procedure outlined by Panse and Sukhatme [5]. The significance of different sources of variations was tested by error mean square using Fisher Snedecor 'F' test of probability at 5 percent level of significance.

3. RESULTS AND DISCUSSION

The number of days taken for flowering and percentage of shots was significantly influenced by PBZ application. With PBZ, an early flowering (79 days) and highest percentage of flowering shoots (85.77) as presented in Table 1 were recorded. The results of the present investigation were in agreement with the findings of many researchers in mango [6,7]. Gibberellic acid inhibits flowering in mango, as higher levels are antagonistic to the formation of flowering primordia and high level of auxin and low level of endogenous gibberellin favours flower bud initiation [8]. Since PBZ is known inhibitor of gibberellin synthesis, its application might have reduced endogenous levels of gibberellins, in order to favour early and profuse flowering. PBZ application induced early and increased flowering in two mango cultivars Dashehari and Banganapalli [9]. The fruit number per panicle at marble and harvesting stage, fruit number per tree and fruit yield were significantly influenced by PBZ treatment. The highest number of fruits per panicle at marble (5.56) and harvesting stages (2.23), highest fruit number per tree (44.52) and fruit yield (8.62 kg per tree) were observed in under PBZ treatment. The effect of PBZ on suppression of growth and increase in fruiting and yield without loss of fruit quality has also been observed in mango by many workers (Hoda et al. [6] Singh and Ranganath.[7])The yield increase with the application of PBZ may be the result of its effect on shifting of assimilates, increasing chlorophyll content, mineral elements and soluble proteins in leaves, stems and roots [10]. Increase in fruit yield in the plants treated with PGRs might be due to resultant effect of growth suppression and better accumulation of nutritional reserves which was probably due to efficiency of plant growth substance in raising C: N ratio toward the optimum for bringing about fruit set as reported by Sen et al. [11].

Plant growth regulators treatments significantly influenced physicochemical characteristics of harvested mango fruits. NAA application showed higher fruit weight (196.67 g), fruit length (9.57 cm), fruit breadth (6.70 cm), pulp weight (122.67 g), and pulp: stone ratio (3.91) [12]. The increase in size of fruit could be due to accelerated rate of cell enlargement and formation of larger intercellular spaces during later part of fruit by exogenous application of NAA. Better fruit weight and pulp to stone ratio as a result of NAA treatments could be due to cell enlargement and possible greater accumulation of sugars and water in expanded cells [12]. It was observed that PGR treatments had significant influence on various fruit quality parameters like TSS, acidity, TSS: Acid ratio, total sugar, reducing sugar, non-reducing and ascorbic acid. PBZ treatment recorded higher TSS, TSS: Acid ratio, total sugar, reducing sugar and ascorbic acid and lower acidity as compared to NAA treatment and control [13,14]. The enhancement in TSS content of fruits by NAA might be due to enhancement in hydrolysis of polysaccharides into soluble sugars and increased mobilization of carbohydrates from the source to sink. Higher TSS: Acid ratio in fruit from PBZ treated plants is probably due to enhancement in the level of TSS and corresponding decrease in acidity content. Fruits from PBZ treated plants showed significantly higher level of reducing and total sugar and is collaborated with the earlier finding in mango. [13]. Such an increase in sugar content by PBZ application may be due to rapid translocation of sugars in larger amount towards fruit and rapid conversion of starch into sugars as well as early maturity of fruits [14]. Application of PBZ resulted in higher level of ascorbic acid as compared to the other treatments in mango [14].

Pre-harvest treatments had significant influence on the PLW of mango fruit at 5 and 15 DAS where NAA treatment showed lowest PLW compared to control. Polyethylene packaging also showed significant influence on the PLW on all dates of observation and was the lowest value as compared to control. With the advancement of storage period, the weight loss significantly increased [15,16]. The higher PLW recorded in control fruits was due to maximum loss of moisture caused by higher rate of transpiration and respiration. Lower PLW of fruits in polyethylene might be due to restriction on diffusion of gases and feedback mechanism resulting into slow rate of transpiration and respiration [17]. The lower weight loss in LDPE film bags might also be due to build up of high RH inside the bags [16]. The interaction of pre and post harvest treatments showed significant influence on the PLW of mango fruits during storage only on 5 DAS.

The firmness of the fruit during storage was influenced by pre-and post-harvest treatments as represented in Table 2. Fruits from NAA and PBZ treated plants showed higher firmness as compared to control and the fruit firmness decreased with increase in storage period in all the treatments. Polyethylene packed fruits retained maximum fruit firmness as compared to control [17]. The better firmness of fruit in polyethylene packed fruit may be due to slower process of ripening as a result of modified atmosphere around the fruit and also due to slower decrease in PLW. Interaction of pre and post-harvest treatments showed significant influence on fruit firmness only at initial and 10 DAS.

The influence of pre- and post-harvest treatments on the sensory qualities of the fruit during storage are reproduced in Table 2. Fruits from PBZ treated plants recorded the highest sensory score as compared to NAA and control on all dates of observation during storage. It was also observed that control fruits exhibited better sensory score than the polyethylene packed fruits. The interaction between pre and post-harvest treatments failed to show any significant influence on the sensory evaluation of mango except at 10 DAS.

The TSS content as influenced by pre- and post-harvest treatments are presented in Table 3. The TSS content was influenced significantly by pre- and post-post harvest treatments where NAA and PBZ treatment showed higher content of TSS on all dates of observation. TSS of fruit increased with increasing period of storage in all treatments. Maximum TSS in NAA and PBZ treatment may be due to rapid hydrolysis of polysaccharides into soluble solids and also due to increased mobilization of carbohydrate from the source to sink with the application of chemicals [14]. The fruits packed in polyethylene bags showed lower level of TSS content than the control. This might be due to higher PLW in control fruits and minimum in polyethylene packed fruits. Polyethylene packing retards the ripening process and associated biochemical changes [18]. The interaction between pre- and post-harvest treatments failed to have any significant impact on the TSS content of fruit on all dates of observation.

It was evident from the data depicted in Table 3 that pre- and post-harvest treatments had significant influence on the acidity content of the fruit during storage. From the data, it could be visualized that pre-harvest treatments had significant influence on the acidity content only on 10 and 15 DAS. Acidity content of fruits decreased with increasing period of storage which might be due to conversion of acid into sugars and their derivatives or is consumed in the process of respiration or both [14]. Polyethylene packaging showed higher level of acidity during the storage period as compared to control. These findings are in agreement with Kumar et al. [15], Jindal et al. [17] and Gautam and Neeraja [18]. The lower content of acidity in control fruits might be due to high respiration and metabolic rate in unpacked fruits resulting into faster conversion of acid into sugar during storage and vice versa for polyethylene packed fruits [17]. The interaction between pre- and post-harvest treatments did not have any significant influence on acid content during storage.

The TSS/Acid ratio was significantly influenced by pre- and post-harvest treatments (Table 3). Highest TSS acid ratio was obtained in PBZ treated fruits. In general, TSS/Acid ratio increased with the increase in the storage period, which was due to higher level of TSS content and corresponding lower level of acidity during storage as influenced by PBZ treatment. Polyethylene packaging showed lower TSS/acid ratio as compared to control which might be due to higher content of acid as a result of slower conversion of acid into sugar during the period of storage [17]. No significant influence of interaction between the pre- and post-harvest treatments was observed on the TSS/acid ratio during the period of investigation.

It was evident from the data represented in Table 4, that pre- and post-harvest treatments had significant influence on the total sugar, reducing sugar and non-reducing sugar content of the fruit during storage. Pre-harvest treatments showed significant influence on the sugar content in mango during the storage period. PBZ treatment recorded the highest value of total sugar, reducing sugars and non-reducing sugars on all dates of observation except at 15 DAS where NAA treatment showed higher content of reducing sugars. Such an increase in sugar

Table 1. Effect of preharvest treatments on flowering, yield and yield attributes of mango

Treatments	Days taken for floweri-ng	Shoots flowered (%)	Fruit/ panicle at marble stage	Fruits /panicle at harvesting stage	Fruits /tree	Yield (kg /tree)	Fruit length (cm)	Fruit breadth (cm)	Fruit wt (g)	Pulp wt (g)	Stone wt (g)	Peel wt (g)	Pulp /stone ratio	TSS (^{0}Brix)	Titratable acidity (%)	TSS: Acid ratio	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar ()%	Ascorbic acid (mg/100g pulp/juice)
P_1 (control)	83.00	65.50	4.83	1.60	29.63	5.52	8.67	5.90	186.33	97.67	33.67	55.00	2.90	9.93	0.81	12.27	6.19	1.97	4.01	42.05
P_2 (NAA @100 ppm)	82.00	73.71	5.51	1.77	37.95	7.69	9.57	6.70	196.67	122.67	31.33	42.67	3.91	11.27	0.77	14.63	8.10	2.13	5.67	43.16
P_3 (PBZ @ 5 ml)	79.00	85.77	5.56	2.23	44.52	8.62	9.50	6.53	193.67	116.33	30.67	46.67	3.80	11.93	0.72	16.54	8.43	2.26	5.86	47.03
Mean	81.33	74.99	5.16	1.87	37.37	7.28	9.25	6.38	192.22	112.22	31.89	48.11	3.54	11.04	0.77	14.48	7.57	2.12	5.21	44.08
CD (5%)	2.0	3.49	0.45	0.32	2.88	0.51	0.10	0.20	5.29	NS	1.20	2.87	0.25	0.75	0.05	1.18	0.39	0.04	0.39	NS

Table 2. Effect of pre and post harvest treatments on PLW, firmness, sensory evaluation and physicochemical properties of mango at initial, 5th, 10th and 15th DAS (days of storage)

Treatments	PLW (%)			Firmness (kg)				Sensory evaluation			
	5th	10th	15th	0th	5th	10th	15th	0th	5th	10th	15th
P_1T_1 (Control + no poly packaging)	9.36	15.12	28.7	4.07	3.13	2.03	1.47	4.33	5.00	4.00	3.33
P_1T_2(Control + poly packaging)	1.80	03.10	06.94	4.77	4.03	3.43	2.73	4.00	4.67	4.00	3.00
P_2T_1 (NAA + no poly packaging)	7.55	12.06	27.79	4.10	3.60	2.80	1.73	4.67	5.00	4.67	3.67
P_2T_2(NAA + poly packaging)	1.60	03.03	06.79	4.83	4.17	3.83	3.03	4.33	4.67	4.00	3.33
P_3T_1(PBZ + no poly packaging)	7.64	14.40	27.83	4.07	3.63	2.80	1.80	4.67	5.00	5.00	4.00
P_3T_2(PBZ + poly packaging)	1.75	03.09	06.88	4.80	4.20	3.80	3.17	4.33	4.67	4.00	3.33
CD (%) = P	0.61	NS	NS	NS	0.17	0.11	0.20	NS	NS	0.30	NS
T	0.51	2.00	0.57	0.52	0.14	0.09	0.16	NS	NS	0.24	NS
P x T	0.87	NS	NS	0.89	NS	0.16	NS	NS	NS	0.42	NS

Table 3. Effect of pre and post harvest treatments on physico-chemical properties of mango at initial, 5^{th}, 10^{th} and 15^{th} DAS (Days of storage)

Treatments	TSS (° Brix)				Titratable acidity (%)				TSS/acid ratio			
	Initial	5^{th}	10^{th}	15^{th}	Initial	5^{th}	10^{th}	15^{th}	Initial	5^{th}	10^{th}	15^{th}
P_1T_1 (Control + no poly packaging)	9.93	12.94	14.45	15.78	0.81	0.60	0.38	0.26	12.27	21.62	38.01	60.69
P_1T_2(Control + poly packaging)	9.60	10.93	12.44	13.78	0.88	0.75	0.58	0.40	11.57	14.77	21.44	34.37
P_2T_1 (NAA + no poly packaging)	11.60	13.27	14.48	17.11	0.77	0.58	0.36	0.21	14.63	22.88	41.32	81.53
P_2T_2(NAA + poly packaging)	11.27	12.60	13.78	15.11	0.81	0.68	0.53	0.36	14.33	18.56	25.83	42.36
P_3T_1(PBZ + no poly packaging)	11.93	13.60	15.11	17.45	0.72	0.53	0.34	0.19	16.54	25.72	44.80	99.13
P_3T_2(PBZ + poly packaging)	11.27	12.27	13.45	14.78	0.78	0.66	0.51	0.32	14.30	18.60	26.36	46.19
CD (%) = P	0.58	0.60	0.58	0.89	NS	NS	0.03	0.04	1.14	2.49	4.00	14.55
T	NS	0.49	0.48	0.72	NS	0.09	0.02	0.04	0.93	2.03	3.2	11.88
P x T	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4. Effect of pre and post harvest treatments on physicochemical properties of mango at initial, 5^{th}, 10^{th} and 15^{th} DAS (days of storage)

Treatments	Total sugar (%)				Reducing sugar (%)				Non- reducing sugar (%)				Ascorbic acid (mg/100g pulp/juice			
	Initial	5^{th}	10^{th}	15^{th}	Initial	5^{th}	10^{th}	15^{th}	Initial	5^{th}	10^{th}	15^{th}	Initial	5^{th}	10^{th}	15^{th}
P_1T_1 (Control + no poly packaging)	6.19	09.36	11.32	12.25	1.97	2.55	3.12	3.62	4.01	6.47	7.80	8.21	42.05	42.05	15.15	11.36
P_1T_2(Control + poly packaging)	6.06	07.60	09.23	10.18	1.68	2.02	2.63	3.08	4.16	5.29	6.26	6.74	43.16	43.16	29.82	18.93
P_2T_1 (NAA + no poly packaging)	8.10	09.83	11.54	14.28	2.13	2.67	3.08	3.80	5.68	6.38	8.05	9.97	43.16	43.16	16.57	11.85
P_2T_2(NAA + poly packaging)	7.79	09.09	10.18	12.53	2.05	2.43	2.83	3.24	5.46	6.33	6.97	8.83	44.27	44.27	31.24	22.25
P_3T_1(PBZ + no poly packaging)	8.43	10.35	12.25	15.01	2.26	2.74	3.19	3.66	5.86	7.23	8.61	10.79	47.03	47.03	17.51	12.31
P_3T_2(PBZ + poly packaging)	7.90	09.23	10.35	11.79	2.06	2.45	2.67	3.15	5.54	6.44	7.02	8.20	49.80	49.80	30.77	21.77
CD (%) = P	0.17	0.11	0.56	0.72	0.012	0.04	0.04	0.05	0.17	0.24	0.42	0.68	3.01	NS	NS	NS
T	0.14	0.09	0.45	0.59	0.01	0.03	0.03	0.04	NS	0.20	0.34	0.55	NS	2.14	2.04	1.49
P x T	NS	0.15	NS	NS	0.02	0.05	0.05	NS	NS	0.34	NS	NS	NS	NS	NS	NS

content by PBZ application was probably due to rapid translocation of sugars in larger amount towards fruit and rapid conversion of starch [14]. Fruits which are packed in polyethylene bags showed lower content of total sugar and reducing sugar as compared to unpacked fruits. The reduced level of total sugar and reducing sugar in polyethylene packed fruits may be due to reduced rate of respiration and slower rate of conversion of starch and polysaccharides into sugars in polyethylene packed fruits as reported by Singh and Narayana [19]. The interaction between pre- and post-harvest treatments did not show any significant influence on total sugar content except at 5 DAS. However, it had significant influence on reducing sugar on all dates of observation.

Among all pre-harvest treatments, PBZ treatment was found to be the most effective resulting in highest level of ascorbic acid in mango fruits [13,14]. The highest level of sugars in PBZ treated fruits might be the possible reason for increase in ascorbic acid content because it is synthesized from sugars. The ascorbic acid content of fruits decreased during storage in all the treatments. The decrease in ascorbic acid content might be due to oxidation of L-ascorbic acid to de-hydro ascorbic acid in the presence of ascorbic acid oxidase. Higher retention of ascorbic acid in fruits packed in polyethylene than control was also observed, which are in conformity with the findings of other research workers [15,16,17]. No significant influence on the interaction between pre and post-harvest treatments was observed on all dates of observation.

It was evident from the data reproduced in Table 5 that pre-harvest treatments followed by post-harvest packaging had significant influence on the shelf life of the fruit during storage. Shelf life of mango fruit was significantly influenced by the PBZ treated plants which showed longest shelf life as compared to NAA treatment and also under control. Polyethylene packed fruits showed longer shelf life than fruits from other treatments [18,20]. This might be due to the modified atmosphere developed inside the sealed polyethylene bag which results in lower level of oxygen and increased carbon dioxide concentration which in turn might have caused reduction in respiration rate leading to low rate of metabolic activities and thereby prolonging the shelf life [21].

Table 5. Effect of pre and post harvest treatments on shelf life of mango

Treatments	Shelf life (days)
P_1T_1 (Control + no poly packaging)	13.00
P_2T_1 (NAA + no poly packaging)	13.33
P_3T_1(PBZ + no poly packaging)	13.67
P_1T_2 (Control + poly packaging)	14.33
P_2T_2 (NAA + poly packaging)	15.00
P_3T_2 (PBZ + poly packaging)	15.33

4. CONCLUSION

Thus, we can conclude from this study that both PBZ @ 5 ml and NAA @ 100 ppm are effective as pre-harvest treatment for enhancing the floral characters, yield and its attributes as well as physicochemical characteristics of fruits. However, PBZ treatment has a slight edge over NAA treatment in relation to most of the parameters. Polyethylene packed fruits had lower PLW, better appearance and firmness, higher ascorbic acid and shelf life, but higher acidity level and lower TSS, sugar and sensory evaluation. PBZ, as well as NAA as pre-harvest treatment with or without polyethylene, can be used for improving quality and shelf life of mango.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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