



Influence of Flower Inducer on Flowering, Yield and Fruit Quality of Mango (*Mangifera indica* L.) cv. Amrapali Planted under Different Spacing

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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

Flowering is the first of several events that lay the foundation for mango production every year. The temperatures below 15°C readily promote floral induction. Decrease in temperature below 20 °C is common in sub-tropical regions but seldom occurs in many tropical ones. So, an alternative strategy for optimum flower initiation under tropical condition is essentially required for increasing the productivity of plant. Among different strategies evolved, paclobutrazol and potassium nitrate application is effective not only in flower induction but also in early and offseason flower production in mango. Hence, an experiment was conducted to study the effect of paclobutrazol and potassium nitrate on the flowering, fruit yield and quality of Amrapali mango (*Mangifera indica* L.) plants grown under different plant spacings at Horticultural Research Station, OUAT, Bhubaneswar during 2018-19 and 2019-20. The experiment was laid out in a Factorial Randomized Block Design with 24 treatment combinations and 2 replications. The treatment combinations consist of four levels of spacings (2.0 x 2.0 m, 4.0 x 2.0 m, 4.0 x 4.0 m, 8.0 x 2.0 m) and 6 levels of chemical treatments (Paclobutrazol@0.25, 0.50 and 0.75 g a.i. per meter of canopy spread and KNO₃@ 2% and 4%) and a control with water application. The results revealed that plants spaced at 4.0 x 4.0 m with application of paclobutrazol 0.50 g a.i. recorded maximum flowering intensity (82.48%), fruit set percentage (6.47%) and yield (11.12 kg/tree). Whereas the fruit quality parameters like TSS, acidity, reducing sugar, total sugar, β carotene content are not significantly influenced by either due to plant spacing or flower inducer such as paclobutrazol and potassium nitrate.

Keywords: Mango; Amrapali; spacing; paclobutrazol; potassium nitrate; flowering; yield; quality.

1. INTRODUCTION

Mango (*Mangifera indica* L.) is one of the most important tropical and subtropical fruits which are being cultivated throughout the world [1]. It is known as the king of fruits in the Indian sub-continent and is believed to be native to South East Asia, especially Indo-Burma regions. India is the largest producer of mangoes in the world [2]. Flowering is the first of several events that lay the foundation for mango production every year. A fundamental understanding of flowering is essential to efficiently utilize cropping management systems, which would extend both the flowering and crop production seasons [3,4]. Flowering is influenced by numerous physiological (carbohydrate reserve and hormonal content) and environmental factors (temperature, rainfall, relative humidity, photoperiod and water stress), among them temperature is one of the major factors which controls flowering phenomenon in most of the fruit crops including mango.

The temperatures below 15°C readily promote floral induction, whereas vegetative growth is generally promoted by warmer temperatures. Decrease in temperature below 20⁰ C, which is common in sub-tropical regions but seldom occurs in many tropical ones. Under field conditions of humid tropical climate, the duration of cool inductive temperature (cold units) for reproductive morphogenesis might not be

sufficient for a specific cultivar, or may revert from inductive to non-inductive conditions before complete floral induction is achieved. So, an alternative to dependence on the environmental stimulus for flower initiation is evolving management strategies substitute for these signals. Among different strategies evolved to induce flowering in mango crop as a substitute to environment signals, KNO₃ application is effective not only in flower induction but also in early and offseason flower induction in mango [5,6].

Physiological factor which influenced flowering is carbohydrate reserve and hormonal content. The consideration to use paclobutrazol to increase the flowering intensity and yield is based on the premise that, PBZ stimulates flowering in weakly inductive shoots of fruit crops [7] by inhibition of gibberellins biosynthesis. The inhibitory effect of GA to flowering, probably arises from its ability to mobilize carbohydrate thereby preventing starch accumulation. Once GA level falls below a threshold, starch can start to accumulate allowing the tree's competence to flower to be expressed. Paclobutrazol, a gibberellins inhibitor, also reduces VP level and thereby increases FP/VP ratio which stimulates flowering shoots in weakly inductive shoots of fruit crops [7]. The influence of Paclobutrazol (PBZ) and potassium nitrate on flowering, yield and fruit quality on mango cv. Amrapali has not been studied under Odisha condition.

Hence, this experiment was designed to determine the ability of paclobutrazol (PBZ) and potassium nitrate (KNO_3) to intensify flowering, fruiting and fruit quality of mango cv. Amrapali planted under different spacing.

2. MATERIALS AND METHODS

The experiment was conducted during 2018-19 and 2019-20 in the Horticulture Research Station, Baramunda, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha. The Horticulture Research Station is about 5 km away from OUAT campus, Bhubaneswar situated at a latitude of $20^{\circ} 16' \text{ N}$ and longitude of $85^{\circ} 47' \text{ E}$ with an altitude of 25.5 m above MSL and about 40 km away from Bay of Bengal. The soil was sandy loam, strongly acidic in reaction and had low organic carbon ($< 0.5\%$) and N content ($< 200 \text{ kg ha}^{-1}$). The experiment was carried out on an 8-year-old existing bearing mango orchard (cv. Amrapali) planted under different density and uniform in vigour and canopy spread. The experiment was laid out in a Factorial Randomized Block Design with 24 treatment combinations and 2 replications. The treatment combinations consist of four levels of spacings (2.0 x 2.0 m, 4.0 x 2.0 m, 4.0 x 4.0 m, 8.0 x 2.0 m) and 6 levels of chemical treatments (Paclobutrazol @ 0.25, 0.50 and 0.75 g a.i. per meter of canopy spread and KNO_3 @ 2% and 4%) and a control with water application.

The quantified amount of PBZ (Lustar- 25% w/v) was dissolved in 20 litres of water and applied around the root zone by making a ring of 20 cm width and 10-15 cm depth with a radius of 1.5 m from the trunk during 1st week of September 2018 and 2019. For preparation of KNO_3 solution @ 2 % and 4 %, 20 g and 40 g KNO_3 dissolved in one litre of water. Foliar spray of prepared solution of KNO_3 as per the treatments were done to the undersides of leaves using tractor operated sprayer because of the high numbers of stomata on the lower surface [8] during 1st week of September and again in 1st week of October, 2018 and 2019. The control trees were treated with water. All the trees were provided with standard orchard management practices including nutrient and pest management.

The flowering intensity was determined on the basis of the number of panicles bearing shoots per square meter canopy area (recorded in four directions) and expressed in percentage. Flowering intensity (%) = (No. of flowering shoots/Total no. of shoots) $\times 100$. The

hermaphrodite flower percentage was determined on the basis of number of staminate and hermaphrodite (bisexual) flowers counted at full bloom ($> 75\%$ flowers were open) in twenty tagged panicles under each treatment. Fruit set percentage was recorded on the basis of number of fruits retained at pea stage (7-8 mm) and number of bisexual flowers. Fruits were harvested separately in each treatment and average was worked out to express the yield in kg tree^{-1} . The shelf life of fruit was noted by keeping the fruits at room temperature and noted the days taken from harvesting to optimum eating stage and expressed in days. Total Soluble Solids (TSS) were measured by digital refractometer (0-85 °Brix, Hanna) and titratable acidity was estimated by 0.1N NaOH method [8]. Ascorbic acid content was estimated in mature fruits by 2,6-dichlorophenolindophenol visual titration method [8]. Reducing sugar was estimated by titrimetric method Lane and Eynon as narrated by Ranganna [9]. The total sugar in the sample was estimated by same method as that of reducing sugar after inversion of the non-reducing sugar using dilute hydrochloric acid and expressed in percentage [9]. β -carotene value was measured as per the procedure given by Zhishen et al. [10]. The statistical analysis was carried out as per Factorial Randomized Block Design suggested by [11]. The level of significance was tested for different variables at 5 per cent level of significance.

3. RESULTS AND DISCUSSION

3.1 Effect of Different Plant Spacing and Chemical Treatment on Flowering and Fruit Set

The data pertaining to flowering intensity was significantly influenced by different plant spacing, chemicals and their interaction is presented in Table 1. Pooled data of two years revealed that the maximum flowering intensity was observed in plant spaced at 4.0 x 4.0 m (72.11 %), whereas lowest flowering intensity was observed in 2.0 x 2.0 m spacing (57.20%). These findings are in consonance with the findings reported by Singh et al. 2001 in high density planting system in 'Amrapali' mango. The maximum flowering intensity was observed in PBZ application @ 0.50 g a.i. (73.98%), which was followed by PBZ application @ 0.75 g a.i. (69.52%) and minimum flowering intensity was recorded in control (51.19%). Similar results were reported by Yeshitela et al. [7]. In interaction effect, maximum flowering intensity was observed in plant spaced

at 4.0 x 4.0 m with application of PBZ @ 0.50 g a. i (82.48%) and the lowest (57.23%) was recorded in plants spaced at 2 x 2 m and not applied with any chemicals (45.36%). Similar results were earlier obtained by Yeshitela et al. [7].

Table 1. Influence of flower inducer on flowering and yield parameters of mango cv. Amrapali planted under different spacing (Pooled mean of 2018-19 and 2019-2020)

Treatments	Flowering intensity (%)	Hermaphrodite flower (%)	Fruit set at pea stage (%)	Fruit yield (kg/tree)	Shelf life of fruit (Days)
Spacing (S)					
S ₁	57.20	10.39	5.17	4.16	14.98
S ₂	62.37	13.11	5.44	6.93	15.05
S ₃	72.11	15.80	6.01	9.36	15.82
S ₄	66.60	15.53	5.90	8.45	15.40
S.E m±	0.14	1.31	0.12	0.17	0.46
C.D. at 5%	0.40	NS	0.35	0.48	NS
Chemical(C)					
C ₁	63.82	13.85	5.90	7.69	15.62
C ₂	73.98	14.56	6.06	8.61	16.97
C ₃	69.52	13.54	5.67	7.26	17.92
C ₄	61.78	13.44	5.48	6.83	13.99
C ₅	67.13	13.99	5.82	7.31	14.65
C ₆	51.19	12.84	4.85	5.67	12.71
S.E m±	0.17	1.61	0.15	0.21	0.56
C.D. at 5%	0.48	NS	0.43	0.59	1.61
Interaction: Spacing (S) x Chemical (C)					
S ₁ C ₁	56.57	10.51	5.43	4.54	15.29
S ₁ C ₂	65.62	11.00	5.56	4.97	16.64
S ₁ C ₃	61.35	10.27	5.20	4.17	17.59
S ₁ C ₄	54.76	10.18	5.02	3.97	13.66
S ₁ C ₅	59.51	10.66	5.36	4.19	14.32
S ₁ C ₆	45.36	9.70	4.45	3.15	12.38
S ₂ C ₁	61.66	13.21	5.71	7.38	15.36
S ₂ C ₂	71.53	13.95	5.85	8.25	16.71
S ₂ C ₃	67.10	12.97	5.48	7.00	17.66
S ₂ C ₄	59.69	12.87	5.29	6.52	13.73
S ₂ C ₅	64.87	13.34	5.62	7.04	14.39
S ₂ C ₆	49.34	12.30	4.68	5.37	12.45
S ₃ C ₁	71.24	15.96	6.31	9.88	16.13
S ₃ C ₂	82.48	16.86	6.47	11.12	17.48
S ₃ C ₃	77.82	15.51	6.05	9.38	18.43
S ₃ C ₄	68.96	15.51	5.84	8.84	14.50
S ₃ C ₅	74.94	16.08	6.21	9.46	15.16
S ₃ C ₆	57.23	14.87	5.17	7.51	13.22
S ₄ C ₁	65.79	15.71	6.16	8.96	15.71
S ₄ C ₂	76.27	16.44	6.36	10.10	17.06
S ₄ C ₃	71.82	15.42	5.95	8.49	18.01
S ₄ C ₄	63.69	15.21	5.75	7.99	14.08
S ₄ C ₅	69.20	15.88	6.10	8.56	14.74
S ₄ C ₆	52.82	14.49	5.09	6.63	12.80
S.E m±	0.34	3.21	0.16	0.19	1.12
C.D. at 5%	0.97	NS	0.45	0.54	NS

S₁: 2 x 2 m (2500 plants/ ha), S₂: 4x 2 m (1250 plants/ ha), S₃: 4 x 4 m (625 plants/ ha), S₄: 8 x 2 m (625 plants/ ha)

C₁: PBZ @ 0.25 g a. i. /m of canopy spread, C₂: PBZ @ 0.50 g a. i. /m of canopy spread, C₃: PBZ @ 0.75 g a. i /m of canopyspread, C₄: 2% KNO₃, C₅: 4% KNO₃, C₆: Control

Table 2. Influence of flower inducer on fruit quality of mango cv. Amrapali planted under different spacing (Pooled mean of 2018-19 and 2019-2020)

Treatments	Total Soluble Solid (^o B)	Titration acidity (%)	Reducing sugar (%)	Total sugar (%)	β carotene (mg/100g pulp wt.)
Spacing (S)					
S ₁	21.08	0.162	4.56	16.81	16.93
S ₂	21.58	0.153	4.85	17.16	17.12
S ₃	21.96	0.128	5.16	17.75	17.32
S ₄	21.72	0.138	4.99	17.65	17.26
S.E m±	0.18	0.008	0.15	0.36	0.43
C.D. at 5%	NS	NS	NS	NS	NS
Chemical(C)					
C ₁	21.58	0.146	5.04	17.39	17.12
C ₂	21.80	0.123	5.15	17.62	17.54
C ₃	21.62	0.136	4.99	17.45	17.29
C ₄	21.57	0.156	4.75	17.32	17.04
C ₅	21.74	0.147	4.88	17.52	17.33
C ₆	21.20	0.165	4.54	16.76	16.63
S.E m±	0.22	0.010	0.18	0.45	0.53
C.D. at 5%	NS	NS	NS	NS	NS
Interaction: Spacing (S) x Chemical (C)					
S ₁ C ₁	21.07	0.160	4.71	16.85	16.90
S ₁ C ₂	21.49	0.140	4.82	17.13	17.31
S ₁ C ₃	21.10	0.153	4.66	16.94	17.06
S ₁ C ₄	21.06	0.173	4.42	16.78	16.82
S ₁ C ₅	21.37	0.163	4.55	17.02	17.10
S ₁ C ₆	20.35	0.183	4.21	16.16	16.41
S ₂ C ₁	21.57	0.153	5.00	17.22	17.09
S ₂ C ₂	21.99	0.133	5.11	17.40	17.50
S ₂ C ₃	21.60	0.143	4.95	17.27	17.25
S ₂ C ₄	21.56	0.163	4.72	17.14	17.00
S ₂ C ₅	21.87	0.153	4.84	17.32	17.29
S ₂ C ₆	20.85	0.173	4.50	16.61	16.59
S ₃ C ₁	21.95	0.130	5.31	17.79	17.28
S ₃ C ₂	21.97	0.107	5.42	18.02	17.70
S ₃ C ₃	22.00	0.117	5.26	17.85	17.45
S ₃ C ₄	21.94	0.137	5.02	17.72	17.20
S ₃ C ₅	21.96	0.130	5.15	17.91	17.51
S ₃ C ₆	21.91	0.147	4.81	17.18	16.78
S ₄ C ₁	21.71	0.140	5.14	17.69	17.22
S ₄ C ₂	21.73	0.113	5.25	17.92	17.64
S ₄ C ₃	21.76	0.130	5.09	17.75	17.39
S ₄ C ₄	21.70	0.150	4.85	17.62	17.14
S ₄ C ₅	21.74	0.140	4.98	17.81	17.43
S ₄ C ₆	21.69	0.157	4.64	17.08	16.72
S.E m±	0.43	0.019	0.37	0.89	1.05
C.D. at 5%	NS	NS	NS	NS	NS

S₁: 2 x 2 m (2500 plants/ ha), S₂: 4x 2 m (1250 plants/ ha), S₃: 4 x 4 m (625 plants/ ha),
S₄: 8 x 2m (625 plants/ ha)

C₁: PBZ @ 0.25 g a. i /m of canopy spread, C₂: PBZ @ 0.50 g a. i /m of canopy spread,
C₃: PBZ @ 0.75 g a. i /m of canopy spread, C₄: 2% KNO₃, C₅: 4% KNO₃, C₆: Control

The minimum percentage of flowering shoots was observed in high density planting because smaller the canopy area available to plants, the higher the tendency to decrease the number of

flowering shoots as reported by Sarker and Rahim [12]. Ramírez and Davenport [13] observed that, in closure spacings, plants encounter competition for water, nutrients, and

more importantly light which reduces the synthesis of carbohydrates necessary for flowering. Application of paclobutrazol inhibit synthesis of kaurene oxidase in the gibberellin-synthesis pathway, stimulates production of flowering shoots during these weakly inductive conditions [7].

Effect of plant spacing on percentage of hermaphrodite flower was found to be non-significant. Chemical treatments had non-significant effect on % of hermaphrodite flower. In contrast to our observations Kishore et al. [14] reported highest percentage of bisexual flowers when PBZ was applied at 0.50 g a.i. m⁻¹ canopy spread. Singh [15] reported that apart from enhancing flowering intensity, PBZ was also effective in increasing sex ratio in mango. It may be presumed that reduction in level of GAs due to PBZ could have stimulated the biosynthesis of ethylene, which is responsible for induction of femaleness in many plants. Moreover, ethylene signalling pathway also mediates the arrest of stamen primordia and in turn reduces the production of male flowers [16,17]. The interaction effect of spacing and chemical treatment showed non-significant effect on hermaphrodite flower %.

The data relating to fruit set (%) as influenced by the plant spacing, different concentrations of paclobutrazol and KNO₃ and their interaction effect is presented in Table 1. The highest fruit set % was recorded in plants planted at a spacing of 4.0 x 4.0 m (6.01 %) which was at par with the spacing of 8.0 x 2.0 m (5.90 %) and the lowest per cent fruit set was recorded in 2.0 x 2.0 m (5.17 %) spacing. The above findings are in line with that of Singh et al. [18] and Sagar et al. [19]. Higher fruit setting in plants under wider spacing seems to be due to greater photosynthetic activity, because of exposure of a greater number of leaves to sun light, that availability of proper sunlight to the lower branches of the trees at close spacing becomes a limiting factor and it adversely affects the flowering and fruiting [18]. Similarly, the chemical treatment without considering the effect of planting densities had significantly affected fruit set %. In the present study, the highest fruit set % (6.06%) was observed in PBZ @ 0.50 g a.i. which was at par with PBZ @ 0.25 g a.i. and 0.75 g a.i. /m of canopy area and KNO₃@ 4% (5.82%). Fruit set is primarily determined by the transfer of viable pollens on the stigma, pollen germination and fertilization and in all the physiological events gibberellins play an

important role. It has been reported that fruit set is reduced significantly if biosynthesis of gibberellins is inhibited by gibberellins inhibitors like paclobutrazol, Serrani et al. [20] Interaction of planting density and chemical content had significant effect on fruit set (%) in mango. Highest fruit set % was recorded in plant spaced at 4.0 x 4.0 m with application of PBZ @ 0.50 g a. i. (6.47%).

3.2 Effect of Different Plant Spacing and Chemical Treatment on Fruit Yield and Shelf Life

The data pertaining to yield per plant (kg) was influenced by different plant densities, chemical treatments and their interaction effects are presented in Table 1. Yield per plant in different spacing was found maximum in 4.0 x 4.0 m (9.36 kg) spacing which was followed by 8.0 x 2.0 m (8.45 kg) and the minimum yield per plant was recorded in the treatment 2.0 x 2.0 m (4.16 kg). These findings are in consonance with the findings reported by Singh et al. [18] in high density planting system in 'Amrapali' mango. Higher yield per plant in wider spacing might be due to larger canopy volume, higher number of flower bearing shoot and higher fruit set percentage, which ultimately increased the yield per plant [18]. Among the different paclobutrazol and KNO₃ applications, the maximum yield per plant was recorded in the paclobutrazol at 0.50 g a.i. (8.61 kg) and the minimum yield per plant was recorded in the treatment control (5.67kg). The above finding is similar to those noted by Yeshitela et al. [7] and Kishore et al. [14]. The interaction of plant spacing and chemicals indicated that the plant spaced at 4.0 x 4.0 m with application of PBZ @ 0.50 g a. i (11.12 kg) recorded maximum yield per plant which was at par with plant spaced at 4 x 4 m and treated with PBZ @ 0.25 g a. i. (9.88 kg) and plant spaced at 8 x 2 m and treated with PBZ @ 0.25 g a. i. (10.10 kg). These results are in line with Upreti et al. [21]. Increased fruit yield owing to paclobutrazol treatment was due to increased number of flowering shoots and reduced vegetative / dormant shoots, compared to the control. This is in line with the work done by Burondkar et al. [22]. Tandel and Patel [23] reported that application of paclobutrazol increased the yield in all cultivars viz., Alphonso, Kesar and Rajapuri.

Plant spacing and interaction effect of spacing and chemical treatment had no significant effect on shelf life of mango cv. Amrapali planted under

different spacing. Whereas chemical treatment had significant effect on shelf life of mango. Highest shelf life was recorded in PBZ treatment @ 0.75 g a.i. (16.97 days) and was at par with PBZ @ 0.50 g a.i. (16.97 days). Minimum shelf life was recorded in control (12.71 days). These findings are in line with Sarker and Rahim [13]. The PBZ can affect the electronic transport which could promote the accumulation of NADH + and H⁺ in fruit cell, being able to reduce the activity of isocitrate dehydrogenase, allosteric enzyme involved in the regulation of Krebs cycle and diminished the CO₂ production. These effects demonstrate that PBZ has a suppressor effect on fruit ripening and an important effect on postharvest life. Similar conformational statements were also being given by Naleo et al. [24].

3.3 Effect of Different Plant Spacing and Chemical Treatment on Fruit Quality Parameters

The fruit quality parameters like TSS, titrable acidity, reducing sugar, total sugar, β carotene and ascorbic acid were not influenced by the planting density, chemical treatments and their interaction effect. Kurian and Iyer [25] had made similar observations in their study on Alphonso mango. Singh et al. [15] reported that there was no significant effect of different planting systems on TSS and acidity of fruits of 'Amrapali' mango (*Mangifera indica* L.) planted under five different planting systems. Similarly, Kumawat et al. [26] also studied the effect of different spacing on newly planted guava cv, L-49 under ultra high-density planting system and found that planting density did not change significantly most variables related to fruit quality such as TSS, acidity, ascorbic acid, sugar content and organoleptic score of fruits. Lolaei et al. [27] and Arzani et al. [28] also reported that there was no improvement in fruit quality with the application of PBZ. However, Arora et al. [29] and Martinez et al. [30] noticed significant improvement in fruit quality of mango with application of KNO₃.

4. CONCLUSION

In high density planting of Amrapali mango, plants spaced at 4.0 x 4.0 m produced more numbers of flowering shoot, percentage of hermaphrodite flower, fruit set and yield in comparison to plant spaced at 8.0 x 2.0 m, 4.0 x 2.0 m, 2.0 x 2.0 m. Among chemical treatments, PBZ @ 0.50 g a.i. application recorded highest flowering intensity, hermaphrodite flower

percentage, fruit set and yield. The interaction of plant spacing of 4.0 x 4.0 m and application of PBZ @ 0.50 g a.i. recorded maximum fruit yield per plant. The fruit quality parameters like TSS, acidity, reducing sugar, total sugar, β carotene content are not influenced by either due to plant spacing or flower inducer such as paclobutrazol and potassium nitrate.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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