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Influence of naphthalene acetic acid, gibberellic acid and triacontanol on fruit retention, yield and quality of mango (*Mangifera indica* L.) cv. Banganpalli

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Abstract

A field investigation was carried out on fifteen-year-old mango cv. Banganpalli during 2021-2023 in the coastal region of India at the research farm of ICAR-IIHR-Central Horticultural Experiment Station, Bhubaneswar, Odisha to evaluate the efficacy of some plant growth regulators, namely naphthalene acetic acid (NAA), gibberellic acid (GA_3) and triacontanol (TRIA) for improving fruit retention, yield and quality of harvest. The experiment was laid out in randomized block design with 10 treatments consisting of NAA (10, 20 and 30 ppm), GA_3 (25, 50 and 75 ppm), TRIA (1, 3 and 5 ppm) and water spray as control. Each treatment was replicated thrice with four plants per replication. Treatments were applied on the plant canopy thrice at panicle initiation, pea and marble stages of fruit growth. Observations were recorded on flowering, fruiting, yield and fruit quality indices. Application of triacontanol at 3-5 ppm brought out a significant improvement over control in terms of panicle size, fruit retention and yield. Plants sprayed with 5 ppm triacontanol produced the largest panicle (length: 29.17 cm, width: 18.07 cm) and recorded the maximum value for fruit retention (68.93, 53.38, 39.41, 32.88, 26.54, 20.46 and 16.58% at 15, 30, 45, 60, 75, 90 and 105 days after pea stage, respectively), number of fruits/tree (104.72) and yield (38.95 kg/tree). With respect to fruit quality, GA_3 and TRIA exhibited significant influence on fractions of fruit, dry matter and on most of the chemical attributes (TSS, TSS/acid ratio, total sugar, reducing sugar, non-reducing sugar and vitamin C) when applied at the concentration of 50-75 and 3-5 ppm, respectively.

Keywords

chlorophyll; fruit retention; fruit quality; gibberellic acid; mango yield; triacontanol

Introduction

Mango *(Mangifera indica* L.; Anacardiaceae; 2n=2x=40) is one of the most popular and widely grown fruits in the tropics and sub-tropics of the world on account of its varietal wealth, production volume, versatile uses, enchanting shades of colour, delightful taste, unique flavour, captivating aroma, excellent nutritional properties and high marketability. It is believed to have originated in the Indo-Myanmar region (1) during the early Cretaceous era (2) and gradually spread throughout Asia and tropical and subtropical regions worldwide over the past 2500 years by travellers, traders and rulers (3). Presently, it is grown in approximately 140 countries (4), however, the mass-scale popularity, economic significance and extensivity of cultivation it enjoys in India is unmatched. Mango has a rich cultivation history of 4,000-6,000 years in India and is deeply intertwined with Indian art, scriptures, history, culture and traditions (5). India is the global leader in mango production with 2.26 million hectares of area and 21.82 million tonnes of

production (6). Despite its rich legacy in mango cultivation and unparalleled global production, the country falls short in tapping the full horticultural potential of mango in terms of productivity. The average productivity of mango in India is 9.66 tonnes/hectare, which is way lower than that realized in other countries, viz., 30 tonnes/hectare in Israel (7). One of the most common and critical constraints in realizing the higher yield potential of mango despite adequate flowering and initial fruit set, is the high magnitude of fruit drop.

Mango fruit drop is a highly complex and coordinated physiological process that involves the formation of a separation layer in the abscission zone, located at the junction of the pedicel and peduncle. Induction of separation layer is regulated by a variety of stress stimuli of biotic and abiotic nature, viz., inadequate pollination, self-incompatibility, incidence of insect pests and diseases and unfavourable soil and climatic conditions responsible for embryo abortion, hormonal imbalance (low levels of auxin, gibberellins and cytokinin coupled with high levels of ethylene and abscisic acid), expression of cell wall degrading enzymes (cellulase and pectinase) and sink rivalry in plant (8, 9). Studies carried out by various investigators suggest the use of plant growth regulators (PGRs), particularly naphthalene acetic acid (NAA), gibberellic acid (GA_3) and triacontanol (TRIA) in mango during flowering and fruiting for controlling the premature abscission of fruits and improving the quantum and quality of harvest (10-15). However, the response of crops to the PGRs may differ with the species, variety, climatic conditions and PGR application timing and concentration. Keeping all these aspects in view, the present investigation was, therefore, undertaken to assess the effects of foliar application of NAA, GA_3 and TRIA on fruit retention, yield and quality in mango cv. Banganpalii in the tropical eastern region of India.

Materials and Methods

The current field trial was conducted at ICAR-IIHR-Central Horticultural Experiment Station, Bhubaneswar, Odisha, India (20°15' N, 85°15' E, 25.5 m amsl) during 2021-2023 on a high-density mango orchard (5 m × 5 m) of cv. Banganpalli, which was planted in 2005 and maintained under uniform cultural practices. The site experiences a hot and humid climate, receiving an annual rainfall of 1400-1500 mm, primarily from June to September. The soil in experimental orchard was red lateritic with sandy loam texture (80.72% sand, 10.65% silt and 8.63% clay), acidic reaction (pH 4.8) and low levels of organic carbon (0.25%) and available nitrogen (191.74 kg/ha), phosphorus (16.45 kg/ha) and potassium (119.86 kg/ha). The trial was carried out employing a randomized block design with 10 treatments and 3 replications. The treatments comprised of varying concentrations of three PGRs which are reported to reduce fruit drop in mango, viz., NAA (T1: 10, T2: 20 and T3: 30 ppm), GA_3 (T4: 25, T5: 50 and T6: 75 ppm) and TRIA (T7: 1, T8: 3 and T9: 5 ppm) and water spray as control (T10). Treatments were applied on the plant canopy thrice during panicle initiation, pea and marble stages of fruit development. Observations were recorded on leaf chlorophyll content; flowering and fruiting characteristics, viz., flowering intensity (%), number of flowers per panicle, hermaphrodite flower intensity (%), panicle size in terms of length and width (cm) and fruit retention (%); yield (kg/tree) and yield contributing attributes, viz., average fruit weight (g/fruit) and no. of fruits/tree; and on fruit quality indices, viz., fractions of fruit (%), dry matter content (%), TSS (°B), acidity (% equivalent of citric acid), TSS/acid ratio, sugar content (%), vitamin C (mg/100g of pulp) and total carotenoid (µg/100g of pulp).

To measure leaf chlorophyll, 20 vegetative shoots that emerged after the first spray of treatments were randomly tagged on each tree covering all four directions of the canopy. Once shoots reached six months of maturity, two leaves were selected from the central portion and the chlorophyll content was measured at 10 random points while avoiding the midrib and direct sunlight, using a portable chlorophyll meter, called atLEAF. The results were expressed as atLEAF units (9, 16). For determining flowering intensity, all three types of shoots (floral, vegetative and dormant) were counted per square meter of tree canopy in all four directions with the help of quadrate and the following formula was used (17)-

$$\text{Flowering intensity (\%)} = \frac{\text{No. of floral shoots}}{\text{Total number of shoots}} \times 100$$

Total number of shoots = dormant shoots + vegetative shoots + floral shoots

To record flowering and fruiting parameters, 20 panicles were randomly tagged across the plant canopy at full bloom stage. A measuring tape was used to record panicle size. The length was measured from base to tip, while the width was at its broadest part. The intensity of the hermaphrodite flower was worked with the help of the following formula (18)-

$$\text{Hermaphrodite flower intensity (\%)} = \frac{\text{No. of hermaphrodite flowers per panicle}}{\text{Total number of flowers per panicle}} \times 100$$

Once the mango tree entered fruit setting phase, fruits were counted periodically on tagged panicles at fortnightly interval starting from pea stage to harvesting stage, subsequently fruit retention at 15, 30, 45, 60, 75, 90 and 105 days after pea stage (DAPS) was computed using following formula (9, 19)-

$$\text{Fruit retention (\%)} = \frac{\text{No. of fruits retained}}{\text{No. of fruits at pea stage}} \times 100$$

On reaching optimum maturity, fruits were harvested manually and the produce was weighed and counted for the purpose of yield data. The average fruit weight was computed using following formula (19).

$$\text{Average fruit weight (g/fruit)} = \frac{\text{Yield (kg/tree)}}{\text{Number of fruits per tree}} \times 1000$$

A random sample of 10 fruits was drawn from the harvest lot of each tree and used for the determination of physico-chemical attributes of fruit quality. Fractions of fruit, i.e., peel,

pulp and stone, were weighed and expressed as percentages. Ten grams of fruit pulp was oven dried at 60 °C until it reaches to a constant dry weight, thereafter following formula was used for the calculation of dry matter (19) -

$$\text{Dry matter content (\%)} = \frac{\text{Dry weight of pulp (g)}}{\text{Fresh weight of pulp (g)}} \times 100$$

The total soluble solids (TSS) in fruit pulp were measured with the help of portable digital refractometer (Hanna HI 96801, 0 -85%). Estimation of acidity, sugar (reducing, non-reducing and total sugar), vitamin C and total carotenoid was performed as per the standard methods (20). The field and laboratory data collected over three consecutive years (2021, 2022 and 2023) were pooled and subjected to statistical analysis using OPSTAT, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India.

Results and Discussion

Flowering

The observations recorded on some important characteristics of flowering are presented in Table 1. No significant improvements were observed in flowering intensity, no. of flowers per panicle and hermaphrodite flower percentage on application of NAA, GA_3 and TRIA, however, a significant improvement in panicle size was recorded with the application of 3-5 ppm TRIA. In PGR treatments, flowering intensity, no. of flowers per panicle and hermaphrodite flower percentage ranged between 67.92-71.57%, 1070.64-1287.49 and 12.72-14.66%, respectively, as against their corresponding values of 68.23%, 1096.90 and 12.15% noted under control. The T9-treated (5 ppm TRIA) mango trees recorded the largest panicles (29.17 cm × 18.07 cm), followed by 3 ppm TRIA (28.65 cm × 17.86 cm). The panicle size in the rest of the PGR treatments (21.66-24.06 cm × 12.07-14.34 cm) did not exhibit notable differences and remained comparable to the control (21.43 cm × 12.41 cm).

The stimulatory effect of triacontanol on mango panicle could be explained by its role in activation of growth-promoting second messenger called L(+)-adenosine and in enhancing the photosynthetic efficiency of plant via upregulation of genes (rbcS) and enzymes (ribulose-1,5-bisphosphate carboxylase, phosphoenolpyruvate carboxylase, carbonic anhydrase, malate dehydrogenase, nitrate reductase) involved in the process and by improving the functioning and expression of various components of photosynthetic apparatus, viz., pigments, membrane permeability, stomatal conductance and PSII (21-27). Our study revealed significant enhancement in leaf chlorophyll due to the application of 3-5 ppm TRIA (Fig. 1) which could be attributed to its positive influence on the size and number of the chloroplast (28). Significant effects of TRIA on growth and leaf chlorophyll content have also been reported earlier in various horticultural crops (9, 26, 29).

Fruit retention and yield

The data pertaining to fruit retention and yield are presented in Table 2. All the PGR treatments and control exhibited a decreasing trend of fruit retention with the advancement of fruit development period. The maximum fruit retention was observed during initial phase of fruit development, i.e., at 15 DAPS (50.97 to 68.93%), whereas, at the final stage of fruit development or maturity, i.e., 105 DAPS, it was minimum (12.17 to 16.58%). The perusal of data in Table 2 further revealed the effectiveness of TRIA in exerting significant influence on fruit retention over NAA and GA_3, when applied at the concentration of 3-5 ppm. The treatment T9 (5 ppm TRIA) recorded the highest fruit retention, which was at par with the T8 (3 ppm TRIA). Fruit retention recorded in 1 ppm TRIA (T7) and all tried concentrations of other PGRs, namely NAA and GA_3 (T1, T2, T3, T4, T5 and T6) were statistically at par with the control.

Triacontanol-induced improvement in fruit retention as observed in the present study might be due to its inhibitory effect on hydrolytic enzymes, viz., cellulase and pectinase responsible for cell wall dissolution (30) and on abscission-inducing plant hormone, called ABA (31). Additionally, TRIA is suggested to enhance the source capacity and sink strength in plants on account of its positive influence on leaf area, water and nutrient uptake, photosynthetic pigments and enzymes and translocation and accumulation of photosynthates, whereas antagonistic effect on respiration and transpiration, which, in turn, could have reduced the fruit abscission and enhanced the fruit retention (27, 32-34). Our study supports TRIA's role in strengthening the source capacity, since mango trees sprayed with 3-5 ppm TRIA had notably high contents of leaf chlorophyll, which is considered an

Table 1. Effect of plant growth regulators on flowering in mango cv. Banganpalli

Treatment	Flowering intensity (%)	No. of flowers/panicle	Hermaphrodite flower (%)	Panicle dimension (cm)	
				Length	Width
T1	68.65	1105.38	12.72	21.92	12.71
T2	69.29	1070.64	13.19	21.66	12.07
T3	71.57	1145.76	13.32	22.47	13.10
T4	70.24	1156.85	13.33	22.82	12.43
T5	67.92	1180.72	13.04	23.85	13.67
T6	71.52	1196.37	13.98	24.06	14.34
T7	70.88	1164.28	13.51	23.49	14.04
T8	69.96	1268.15	14.13	28.65	17.86
T9	69.71	1287.49	14.66	29.17	18.07
T10	68.23	1096.90	12.15	21.43	12.41
SE(m)±	2.10	130.47	1.40	1.36	1.02
CD *(P=0.05)*	ns	ns	ns	4.12	3.10

T1: 10 ppm NAA, T2: 20 ppm NAA, T3: 30 ppm NAA, T4: 25 ppm GA_3, T5: 50 ppm GA_3, T6: 75 ppm GA_3, T7: 1 ppm TRIA, T8: 3 ppm TRIA, T9: 5 ppm TRIA, T10: Control, ns: non-significant

Table 2. Effect of plant growth regulators on fruit retention and yield in mango cv. Banganpalli

Treatment	Fruit retention (%)							Fruit yield		
	15 DAPS	30 DAPS	45 DAPS	60 DAPS	75 DAPS	90 DAPS	105 DAPS	No. of fruits/ tree	Fruit weight (g/fruit)	Yield (kg/tree)
T1	52.08	39.67	29.81	24.86	20.05	15.44	12.45	79.54	371.70	29.56
T2	53.18	41.15	30.45	25.37	20.48	15.78	12.76	80.91	372.56	30.12
T3	55.12	42.67	31.52	26.35	21.23	16.35	13.20	84.50	373.15	31.54
T4	53.80	41.65	30.76	25.67	20.72	15.96	12.85	81.75	369.81	30.21
T5	56.14	43.58	32.13	26.78	21.61	16.65	13.45	84.14	370.50	31.16
T6	58.32	45.12	33.06	27.73	22.35	17.31	13.82	88.12	371.34	32.71
T7	57.45	44.46	32.85	27.42	22.12	17.04	13.76	87.12	371.65	32.35
T8	66.51	51.50	38.10	31.76	25.62	19.78	15.95	101.21	372.80	37.72
T9	68.93	53.38	39.41	32.88	26.54	20.46	16.58	104.72	372.14	38.95
T10	50.97	39.45	29.17	24.48	19.67	15.12	12.17	77.46	371.35	28.76
SE(m)±	2.52	1.95	1.40	1.14	0.90	0.89	0.61	3.70	3.72	1.41
CD *(P=0.05)*	7.60	5.81	4.17	3.42	2.73	2.61	1.78	11.15	ns	4.17

T1: 10 ppm NAA, T2: 20 ppm NAA, T3: 30 ppm NAA, T4: 25 ppm GA_3, T5: 50 ppm GA_3, T6: 75 ppm GA_3, T7: 1 ppm TRIA, T8: 3 ppm TRIA, T9: 5 ppm TRIA, T10: Control, ns: non-significant

important indicator of photosynthetic efficiency (Fig. 1). The beneficial effect of triacontanol on fruit retention has also been reported earlier in a variety of fruit crops, such as mango (10, 35), olive (36), pomegranate, (37), mandarin (38) and apple (39).

Foliar application of TRIA (3-5 ppm) not only enhanced the fruit retention but also yielded significant improvement in the quantum of harvest over control. Plants sprayed with 5 ppm TRIA (T9) recorded the highest quantum of fruit yield (38.95 kg/tree, 104.72 fruits/tree), which remained statistically comparable to the yield noted in case of T8 (3 ppm TRIA). On the other hand, the lowest quantum of produce was observed control plants (28.76 kg/tree, 77.46 fruits/tree). Concerning fruit weight, it ranged between 369.81 to 373.15 g/fruit with a mean of 371.74 g/fruit under PGR treatments. However, none of the PGR treatments registered significant improvement over control (371.35 g/fruit). The pronounced effect of TRIA (3-5 ppm) on fruit yield in the present investigation could be resultant of better fruit retention, as other variables influencing the quantum of fruit harvest, viz., flowering intensity, no. of flowers per panicle, hermaphrodite flower % and fruit weight remained unaffected (Table1 and Table 2). Similar effects of TRIA on quantum of mango harvest have been documented previously (15, 33, 35, 40).

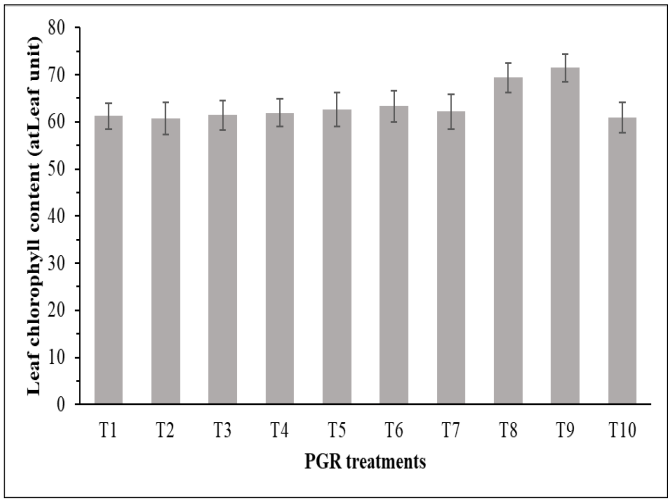

Fig. 1. Effect of plant growth regulators on leaf chlorophyll content in mango cv. Banganpalli.

T1: 10 ppm NAA, T2: 20 ppm NAA, T3: 30 ppm NAA, T4: 25 ppm GA_3, T5: 50 ppm GA_3, T6: 75 ppm GA_3, T7: 1 ppm TRIA, T8: 3 ppm TRIA, T9: 5 ppm TRIA, T10: Control.

Fruit quality

The data recorded on various physical and chemical fruit quality attributes are presented in Table 3. Of three PGRs, GA_3 and TRIA exhibited significant influence on fractions of fruit, dry matter and on most of the chemical parameters studied except acidity and total carotenoid, when applied at the concentration of 50-75 and 3-5 ppm, respectively. Among four effective PGR treatments (T5,

Table 3. Effect of plant growth regulators on fruit quality in mango cv. Banganpalli

Treatment	Pulp (%)	Peel (%)	Seed (%)	Dry matter (%)	TSS (°B)	Acidity (%)	TSS/ Acid ratio	Total Sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Vit. C (mg/100g)	Total carotenoid (µg/100g)
T1	69.89	16.69	13.42	16.12	17.56	0.43	40.84	15.48	9.35	6.13	32.46	795.45
T2	68.72	17.20	14.08	15.67	17.75	0.41	43.29	14.96	9.12	5.84	31.74	835.16
T3	70.10	16.75	13.15	16.17	18.12	0.44	41.18	15.31	9.15	6.16	32.68	819.42
T4	69.41	16.96	13.63	15.89	18.37	0.42	43.74	15.25	9.21	6.04	33.25	876.97
T5	74.63	14.12	11.25	18.64	19.58	0.39	50.21	17.74	10.72	7.02	38.89	841.56
T6	75.54	13.70	10.76	19.35	19.73	0.37	53.32	18.12	10.97	7.15	40.97	902.28
T7	69.60	17.05	13.35	16.25	18.20	0.43	42.33	15.63	9.56	6.07	33.18	798.95
T8	74.92	13.90	11.18	18.97	19.65	0.40	49.13	17.90	10.83	7.07	39.63	837.14
T9	75.17	13.86	10.97	19.78	19.81	0.38	52.13	18.31	11.06	7.25	41.21	865.71
T10	69.16	17.30	13.54	15.72	17.68	0.43	41.12	14.75	9.03	5.72	31.25	810.37
SE(m)±	1.38	0.72	0.46	0.72	0.27	0.03	1.72	0.58	0.26	0.21	1.71	67.65
CD @5%	4.12	2.17	1.35	2.14	0.86	ns	5.21	1.72	0.78	0.65	5.16	ns

T1: 10 ppm NAA, T2: 20 ppm NAA, T3: 30 ppm NAA, T4: 25 ppm GA_3, T5: 50 ppm GA_3, T6: 75 ppm GA_3, T7: 1 ppm TRIA, T8: 3 ppm TRIA, T9: 5 ppm TRIA, T10: Control, ns: non-significant

T6, T8 and T9), the treatment T6 (75 ppm GA_3) registered the highest pulp content (75.54%) and the lowest contents of peel (13.70%) and seed (10.76%), followed by T9 (5 ppm TRIA), T8 (3 ppm TRIA) and T5 (50 ppm GA_3), however, the variations were non -significant. Fruits with the highest dry matter content (19.78%) were harvested from T9-treated plants, whereas the lowest with T2 treatment (15.67%), which was comparable with the content recorded under control and other non-effective PGR treatments (NAA: T1 and T3; GA_3: T4; TRIA: T7). Similar effects of GA_3 and TRIA on fruit fractions and dry matter have been reported previously in mango, mandarin and sugar apple (9, 10, 41-43).

Perusal of fruit quality data further revealed that effective PGR treatments (T5: 50 ppm GA_3, T6: 75 ppm GA_3, T8: 3 ppm TRIA and T9: 5 ppm TRIA) did not vary significantly with each other for various chemical attributes. Of these, 5 ppm TRIA scored the highest value for TSS (19.81°B), total sugar (18.31%), reducing sugar (11.06%), non-reducing sugar (7.25%) and vitamin C (41.21 mg/100 g pulp), whereas the treatment 75 ppm GA_3 recorded the maximum value for TSS acid ratio (53.32). Control plants recorded the lowest value for total sugar (14.75%), reducing sugar (9.03%), non-reducing sugar (5.72%) and vitamin C (31.25 mg/100 g pulp), on the other hand, the lowest value for TSS and TSS/acid ratio were observed under 10 ppm NAA (17.56 °B and 40.48, respectively). Triacontanol and GA_3-mediated improvement in various chemical attributes of fruit quality have been noticed previously by several researchers (33, 40, 44-47).

The positive influence of GA_3 on various parameters of fruit quality could be ascribed to its role in cell division, cell enlargement, cell elongation, water absorption, nutrient uptake, metabolite synthesis, conversion of complex polysaccharides into simple and soluble sugar molecules, assimilate partitioning, dry matter accumulation, and synthesis of vitamin C precursor called glucose-6-phosphate (44, 48-50). Likewise, TRIA also regulates an array of metabolic, physiological, and biochemical processes in plants including cell division, elongation, expansion, and differentiation (33, 51). Exogenous application of TRIA has stimulatory effects on photosynthesis, enzymatic activity, water uptake, nutrient acquisition, carbohydrate metabolism, translocation, and accumulation of metabolites and photosynthates to the sink, all of which in turn could have resulted in enhancement in physical and chemical attributes of fruit quality (34, 42, 52).

Conclusion

Based on experimental results, it could be concluded that in mango cv. Banganpalli, three foliar sprays of triacontanol @ 3-5 ppm during panicle initiation, pea and marble phases of fruit development are efficacious for controlling premature fruit shedding and improving the yield and quality of harvest.

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Authors' contributions

DS was responsible for conceptualization, investigation, methodology, data recording, statistical analysis, writing the original draft and reviewing and editing the manuscript. KK contributed to methodology and data recording. SB focused on data recording, while GCA provided methodological input, technical guidance and monitoring of the experiment.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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