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QUALITY ENHANCEMENT AND SHELF-LIFE EXTENSION IN MANGO (*MANGIFERA INDICA* L.) CV. BANGANAPALLI THROUGH PLANT GROWTH REGULATORS, CHEMICAL SPRAYS AND PRUNING

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ABSTRACT

An experiment was conducted to assess the effects of foliar spray of plant growth regulators (NAA, salicylic acid, ethrel and cycocel), chemicals (KNO_3 and KH_2PO_4) and pruning on quality attributes of the mango cv. Banganapalli. The results revealed that, KNO_3 @ 1% resulted in maximum shelf life (15 days), enhanced fruit firmness (1.35 kg/cm^2), higher ascorbic acid content (23.22 mg/100g) and minimum physiological loss in weight (6.02%, 12.12%, 18.00% and 23.96%) at 3, 6, 9 and 12 days after harvest (DAH). While, ethrel @ 200 ppm led to the lowest titrable acidity (0.36%) and the highest TSS (18.63%), brix acid ratio (52.50), total carotenoids (2.18 mg/100g), total sugars (12.02%), reducing sugars (3.54%) and non-reducing sugars (8.48%). Meanwhile, the maximum total phenolic content (51.42 mg/100g) was recorded in the plants treated with salicylic acid @ 100 ppm. KNO_3 @ 1% proved beneficial for prolonging shelf life, maintaining firmness, and enriching ascorbic acid with minimal physiological weight loss, while ethrel @ 200 ppm excelled in improving TSS, acidity profile, carotenoid content, and sugar composition.

***Key words*:** Mango, growth regulators, potassium nitrate, ethrel, pruning and fruit quality.

Introduction

Mango (*Mangifera indica* L.), commonly called as the "King of Fruits" or Pride fruit of India, is a tropical drupe of the family Anacardiaceae, order Sapindales, with a chromosome number of 2n = 4x = 40 (Mukherjee, 1950). The Indo-Burma region is identified as its center of origin (De Candolle, 1904). Mango fruit is nutritionally valuable, being the richest source of vitamin A (4800 IU) and a good source of vitamin C (36.4 mg/100 g), vitamin B_6 (pyridoxine), potassium (168 mg/100g) and magnesium (10mg/100g) (Lauricella *et al.*, 2017). Each 100 g of edible pulp provides about 60 kcal. Its pulp is especially high in beta-carotene and natural sugars like sucrose, glucose, and fructose (Bayarri *et al.*, 2001). Beyond fresh consumption, ripe fruits are transformed into several processed forms like jam, jelly, squash, nectar, custard powder, and baby foods, which increase their shelf life and market value. India remains the world leading producer of mango, contributing around 41% of global output (FAO, 2022).

Andhra Pradesh is the second largest producer of mangoes with the production of 1.2 million tonnes annually, contributing 22% to the national yield. The state grows a range of mango varieties, including Banganapalli, Chinna Rasalu, Pedda Rasalu, Totapuri, Neelam, and Suvarnarekha. Banganapalli, a GI-tagged mango cultivar of Andhra Pradesh, that occupies nearly 70% of the total mango cultivation area, majorly grown in Banaganapalle, Paanyam and Nandyal mandals and Rayalaseema region and coastal Andhra region and also in parts of Telengana (Meena *et al.*, 2022). It is highly valued for its export potential due to its excellent taste, characteristic aroma and low fibre content.

Despite these advantages, it suffers from the persistent problem of alternate bearing, which limits the production and productivity, by causing irregular fruiting cycles with heavy yield in one year and light yield or even crop failure in the next (Kumar *et al.,* 2021). The application of plant growth regulators, chemicals and pruning help to regulate vegetative and reproductive growth phases, stimulate uniform flowering, and balance the crop load, thus mitigating the effects of alternate bearing. Foliar application of PGRs is particularly effective because the active substances are rapidly absorbed through the stomata and cuticular pathways of the leaves, and then translocated to various plant organs to meet physiological and metabolic requirements (Maurya *et al.,* 2020). The application of plant growth regulators (PGRs), chemicals and pruning not only enhance yield but also improve key fruit quality attributes such as fruit size, fruit weight, TSS, ascorbic acid, carotenoids, phenols and total sugars. (Vejendela *et al.,* 2008). In light of the views highlighted above, the present investigation was undertaken to ascertain the impact of plant growth regulators, chemical treatments and pruning practices on quality attributes of mango.

Materials and Methods

The present investigation was carried out at Fruit Science block in Dr. YSRHU- College of Horticulture, Anantharajupeta, Annamayya district, Andhra Pradesh in 2024-25 to study the influence of plant growth regulators (PGRs), chemicals and pruning on mango cultivar Banganapalli. The experiment was laid out in a Randomized Block Design (RBD) comprised of nine treatments *viz*., T_1 (NAA @ 20 ppm), T_2 (Salicylic acid @ 100 ppm), T_3 (Ethrel @ 200 ppm), T_4 (Cycocel @ 1%), T_5 (KNO_3 @ 1%), T_6 (KH_2PO_4 @ 1%), T_7 (Pruning back to 1st whorl of leaves), T_8 (Pruning back to 2nd whorl of leaves), T_9 (Control) with three replications.

Plant growth regulators (PGRs) and chemical treatments were applied twice: the initial foliar spray in the second fortnight of September followed by a second foliar spray in the first fortnight of November. Pruning was carried during the second fortnight of July. The following observations were recorded after harvest of mango fruits.

Shelf life (days)

Shelf life was recorded using six fruits per treatment kept at room temperature. Each fruit was thoroughly scrutinized for any visible symptoms of spoilage every day and shelf-life was considered ended when 30 per cent of the fruits shown over ripening or spoilage symptoms.

Fruit firmness (kg/cm^{-2})

The firmness of the fruit was tested by means of a pocket penetrometer (FR-5120 Digital Fruit Firmness Tester).

Physiological loss in weight (%)

Physiological loss in weight (PLW) of fruits was determined by weighing the fruits immediately after harvesting and was recorded as the initial fruit weight. There after they were weighed periodically after every two days interval up to fifteen days of storage at ambient temperature which served as the final weight. The physiological loss in weight was determined by using the following formula and expressed as percentage.

$$\text{PLW}(\%) = \frac{\text{Initial weight of fruit - Final weight of fruit}}{\text{Initial weight of fruit}} \times 100$$

Total soluble solids (°Brix)

Total soluble solids were recorded after extracting the juice from the homogenized pulp using a RX-5000 digital refractometer (ATAGO, Japan).

Titrable acidity (%)

Titrable acidity was determined by titration of the juice extracted after homogenization of the pulp in a mixer against 0.1N NaOH solution using Phenolphthalein as an indicator and the results were expressed in percentage of citric acid (AOAC, 1990).

$$\text{Titrable acidity (\%)} = \frac{\text{Titre value} \times 64 \times \text{Normality of NaOH}}{\text{Volume of sample taken}} \times 100$$

Sugar acid ratio

Sugar-acid ratio is a measurement of the balance between sweetness and acidity in a fruit or juice. It is calculated by

$$\text{Sugar acid ratio} = \frac{^{o}\text{Brix}}{\%\ \text{Acidity}}$$

Ascorbic acid content (mg/100 g pulp)

Ascorbic acid in the pulp was determined using the titrimetric procedure described by Ranganna (2004). The content was subsequently calculated with the formula below.

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Titre value} \times \text{Dye factor} \times \text{Volume made up}}{\text{Aliquot of extract taken} \times \text{Weight of volume of sample}} \times 100$$

Total carotenoids (mg 100g^{-1})

Carotenoid content in mango fruit pulp was estimated by using the methodology of Srivastava and Kumar (2007).

$$\text{Carotenoid content (mg/100g)} = \frac{\text{Optical density (OD)} \times 3.8 \times 100}{\text{Weight of sample (g)} \times 1000}$$

Total phenols (mg 100 g^{-1})

The phenol content was estimated based on the method developed by Singleton and Rossi (1965).

Total sugars (%)

Total sugars in each fruit were determined by the method explained by Yemm and Willis (1954).

Reducing sugars (%)

The di nitro salicylic acid (DNSA) method suggested by Miller (1959) was adopted for the estimation of reducing sugar content in the sample.

Non reducing sugars (%)

The quantum of non-reducing sugars was calculated by substracting reducing sugars from total sugars as reported by Ranganna (1986) using the following formula

Not reducing sugars (%) = Total sugars (%) - Reducing sugar (%)

Results and Discussion

Shelf life (days)

The maximum shelf life was recorded with KNO_3 @ 1%, which extended the fruits up to 15.00 days, and was statistically on par with salicylic acid @ 100 ppm, which maintained the shelf life for 13.50 days. This was followed by KH_2PO_4 @ 1% (T_6) and NAA @ 20 ppm (T_1), which extended the shelf life up to 13.00 and 12.83 days, respectively. The lowest shelf life was observed in the control (T_9), with 11.33 days. The extended shelf life recorded with KNO_3 treatment may be attributed to its role in strengthening cell wall and membrane stability through regulation of pectin metabolism. Further it maintains cell turgor by minimizing water loss via transpiration and respiration rates. These findings are supported by Bibi *et al.,* (2019) in mango cv. Summer Bahisht (SB) Chaunsa.

Fruit firmness (kg/cm²)

The highest fruit firmness was recorded with KNO_3 @ 1% (T_5) with 1.35 kg/cm², which was statistically on par with KH_2PO_4 @ 1% (T_6) with 1.27 kg/cm², NAA @ 20 ppm (T_1) with 1.25 kg/cm², and salicylic acid with 1.24 kg/cm². These were followed by pruning back to 1st whorl of leaves (T_7) which recorded 1.22 kg/cm². The lowest fruit firmness was observed in the control (T_9) with 0.95 kg/cm². KNO_3 application resulted in maximum fruit firmness, possibly due to increased osmolyte accumulation and elevated potassium concentration, which together contributed to higher pressure potential in mesocarp tissues (Lester *et al.,* 2006). Consistent outcomes were also reported by Alebidi *et al.,* (2023) in mango cv. Ewais.

Table 1: Influence of PGRs, chemicals and pruning in mango cv. Banganapalli on shelf life, fruit firmness, TSS, titrable acidity and Brix acid ratio.

Treatments	SL	FF	TSS	TA	BAR
T_1	12.83	1.25	18.07	0.51	35.87
T_2	13.50	1.24	17.60	0.58	31.42
T_3	12.67	1.18	18.63	0.36	52.50
T_4	12.50	1.17	17.73	0.64	27.71
T_5	15.00	1.35	18.43	0.43	43.84
T_6	13.00	1.27	17.90	0.54	32.92
T_7	12.67	1.22	17.43	0.61	29.32
T_8	11.50	1.18	17.30	0.67	26.26
T_9	11.33	0.95	16.80	0.72	23.49
SE(m)	0.63	0.04	0.16	0.05	2.91
C.D. (5%)	1.89	0.13	0.47	0.14	8.73

SL: Shelf life (days); **FF:** Fruit firmness (kg/cm²); **TSS:** TSS (°Brix); **TA:** Titrable acidity (%); **BAR:** Brix acid ratio

Total Soluble solids (TSS) (° Brix)

Among the treatments, ethrel @ 200 ppm (T_3) exhibited the highest TSS with 18.63°Brix, which was on par with KNO_3 @ 1% (T_5) (18.43°Brix). This was followed by NAA @ 20 ppm (T_1) (18.07°Brix), KH_2PO_4 @ 1% (T_6) (17.90°Brix) and Cycocel @ 1% (T_4) (17.73°Brix). The lowest TSS (16.80°Brix) was observed in the control (T_9), indicating the positive influence of growth regulators and chemicals in increasing TSS. This increase in TSS with ethrel application can be attributed to its role in accelerating fruit ripening, which promotes the breakdown of complex carbohydrates like starch and pectin into simple soluble sugars, thereby directly elevating total soluble solids (Gupta and Brahmachari, 2004). Similar findings were reported by Kaur (2017) in mango cv. Amrapali and Dhaneshwari *et al.,* (2023) in mango cv. Dashehari.

Titrable acidity (%)

Among different treatments, the minimum titratable acidity was recorded in ethrel @ 200 ppm (T_3) at 0.36%, which was on par with KNO_3 @ 1% (T_5) at 0.43%. This was followed by NAA @ 20 ppm (T_1), KH_2PO_4 @ 1% (T_6) and salicylic acid @ 100 ppm (T_2) showed 0.51%, 0.54% and 0.58% acidity, respectively. The highest titratable acidity (0.72%) was found in control fruits (T_9). Ethrel facilitates the enzymatic breakdown and conversion of organic acids, such as citric acid and malic acid into sugars and other metabolites, which led to reduction in acid content. These findings are in the line with the reports of Kaur (2017) in mango cv. Amrapali, Yashoda *et al.,* (2006) in Alphonso mango, Gurjar *et al.,* (2017) in mango cv. Dashehari, and Dhaneshwari *et al.,* (2023) in mango cv. Dashehari who observed a decline in percent acidity as the fruit ripens and during storage.

Fig. 1: Influence of PGR's, chemicals and pruning on physiological loss in weight in mango cv. Banganapalli.

Table 3: Influence of PGR's, chemicals and pruning in mango cv. Banganapalli on ascorbic acid, total carotenoids, total phenols, total sugars, reducing sugars and non-reducing sugars.

Treatments	AC	TC	TP	TS	RS	NRS
T_1	21.60	1.79	48.90	10.35	3.26	7.09
T_2	19.20	1.26	51.42	11.12	3.03	8.09
T_3	21.30	2.18	42.27	12.02	3.54	8.48
T_4	19.80	1.14	44.81	11.31	3.09	8.22
T_5	23.22	1.85	47.46	11.72	3.43	8.49
T_6	20.40	1.68	48.76	11.56	3.17	8.39
T_7	19.20	1.27	40.17	10.75	2.78	7.97
T_8	18.60	1.41	39.43	10.52	2.61	7.91
T_9	17.40	1.05	37.82	10.05	2.22	7.84
SE(m)	0.32	0.11	0.59	0.15	0.05	0.14
C.D. (5%)	0.97	0.34	1.77	0.45	0.16	0.43

AC: Ascorbic acid (mg/100g); **TC:** Total carotenoids (mg/100g); **TP:** Total phenols (mg/100g); **TS:** Total sugars (%); **RS:** Reducing sugars (%); **NRS:** Non-reducing sugars (%)

Brix acid ratio

Among different treatments, ethrel @ 200 ppm (T_3) recorded the maximum brix acid ratio of 52.50, which was statistically on par with KNO_3 @ 1% (T_5) (43.84). It was followed by NAA @ 20 ppm (T_1), salicylic acid @ 100 ppm (T_2) and KH_2PO_4 @ 1% (T_6) showed values of 35.87, 31.42 and 32.92, respectively. The minimum brix acid ratio was observed in the control (T_9), which recorded 23.49. Dual role of ethrel in higher sugar accumulation and reduced acid concentration leads to a significant enhancement of the sugar–acid ratio, improving the sweetness, flavor, and overall eating quality of the fruits

Physiological loss in weight (%)

Physiological loss in weight (PLW) of fruits increased progressively with storage duration across all treatments, with no significant differences observed after 3 DAH. Minimum PLW of 12.12%, 18.00% and 23.96% was observed in KNO_3 @ 1% (T_5) after 6, 9, and 12 days after harvest, respectively. These values are on par with NAA @ 20 ppm (T_1) (13.20%, 19.23% and 25.34%), KH_2PO_4 @ 1% (T_6) (13.54%, 19.70% and 25.66%) and cycocel @ 1% (T_4) (13.63%, 19.78% and 25.93%) during the same intervals. The highest PLW was observed in control (T_9), which registered 15.09%, 22.03% and 30.56% at the corresponding intervals. It was evident from the study that application of KNO_3 @ 1% significantly minimized postharvest physiological weight loss, resulting in extended shelf life of mango fruits. Similar observations were recorded by Singh *et al.,* (2019) in mango cvs. Bombay Green, Dashehari and Langra, Vishwakarma *et al.,* (2022) in mango cv. Amrapali and Devi *et al.,* (2023) in mango cv. Banganapalli.

Table 2: Influence of PGR's, chemicals and pruning on physiological loss in weight in mango cv. Banganapalli.

Treatments	Physiological loss in weight (%)			
	3 DAH	6 DAH	9 DAH	12 DAH
T_1 - NAA @ 20 ppm	6.81	13.20	19.23	25.34
T_2 – Salicylic Acid @ 100 ppm	6.92	13.92	20.41	26.60
T_3 - Ethrel @ 200 ppm	7.01	13.75	20.22	26.54
T_4 - Cycocel @ 1%	7.05	13.63	19.78	25.93
T_5 - KNO_3 @ 1%	6.02	12.12	18.00	23.96
T_6 - KH_2PO_4 @ 1%	6.87	13.54	19.70	25.66
T_7 - Pruning back to 1st whorl of leaves	8.05	14.94	21.44	27.49
T_8 - Pruning back to 2nd whorl of leaves	7.64	14.46	20.62	26.67
T_9 - Control	8.27	15.09	22.03	30.56
SE(m)	0.49	0.55	0.66	0.88
C.D. (5%)	NS	1.65	1.97	2.65

Ascorbic acid (mg/100g)

The maximum Vitamin C content was recorded with KNO_3 @ 1% (T_5) at 23.22 mg/100 g, which was significantly superior to all other treatments. This was followed by NAA @ 20 ppm (T_1), ethrel @ 200 ppm (T_3), and KH_2PO_4 @ 1% (T_6), which recorded 21.60 mg/100 g, 21.30 mg/100 g and 20.40 mg/100 g respectively. The lowest Vitamin C content was noted in the control (T_9) with 17.40 mg/100 g. The enhancement of ascorbic acid content following potassium nitrate (KNO_3) application is largely attributed to the continuous synthesis of glucose-6-phosphate, an essential precursor in the vitamin C biosynthesis pathway throughout fruit development (Chouhan *et al.*, 2025). These observations are consistent with the findings of Das and Dutta (2022) in litchi cv. Bombai, Sarker and Rahim (2013) in mango cv. Amrapalli, Thiruezhirselvan *et al.,* (2024) in mango cv. Banganapalli and Das *et al.,* (2017) in mango cv. Himsagar.

Total carotenoids (mg/100g)

The highest carotenoid content of 2.18 mg/100 g was recorded with ethrel @ 200 ppm (T_3) cycocel @ 1% (T_4), which was statistically superior to all other treatments. This was followed by KNO_3 @ 1% (T_5) with 1.85 mg/100 g, NAA @ 20 ppm (T_1) with 1.79 mg/100 g, and KH_2PO_4 @ 1% (T_6) with 1.68 mg/100 g. The lowest values were obtained with control (T_9), which registered only 1.05 mg/100 g. Ethrel plays a role in activating carotenoid biosynthetic genes such as phytoene synthase

(PSY) and lycopene β-cyclase, leading to increased synthesis of pigments like β-carotene and lutein (Gurjar *et al.*, 2017). It promotes chlorophyll degradation, enabling the color transition from green to yellow–orange, leading to increased carotenoid accumulation. Enhanced intensity of yellow and red coloration with higher ethrel levels suggests increased carotenoid buildup in the ripening fruit (Deepa *et al.*, 2016).

Total phenols (mg/100g)

The highest total phenol content was recorded in salicylic Acid @ 100 ppm (T_2) (51.42 mg/100 g), followed by NAA @ 20 ppm (T_1) (48.90 mg/100 g) and KH_2PO_4 @ 1% (T_6) (48.76 mg/100 g). KNO_3 @ 1% (T_5) also recorded relatively high phenol content (47.46 mg/100 g). The untreated control (T_9) exhibited the minimum total phenol content (37.82 mg/100 g). Salicylic acid application stimulates phenylalanine ammonia-lyase, which plays a central role in phenolic biosynthesis (Prasad and Sharma, 2018). In addition, by inducing antioxidant enzymes including superoxide dismutase, catalase and ascorbate peroxidase, salicylic acid reduces oxidative stress and supports the retention of phenolic compounds during storage (Damodaram *et al.*, 2015; Singh *et al.*, 2020).

Total sugars (%)

The highest total sugars of 12.02% were recorded in ethrel @ 200 ppm (T_3), which was statistically on par with KNO_3 @ 1% (T_5) (11.72%). This was followed by KH_2PO_4 @ 1% (T_6) (11.56%), cycocel @ 1% (T_4) (11.31%), salicylic acid @ 100 ppm (T_2) (11.12%), and pruning back to 1st whorl of leaves (T_7) (10.75%). The control (T_9) registered the lowest total sugar content (9.99%). The increase in total sugar content with ethrel application could be linked to its ability to accelerate the respiration and the conversion of carbohydrates into sugars through oxidation (Kaur, 2017). It activates enzymes such as invertase, sucrose synthase, and amylase, which catalyze the hydrolysis of starch and complex carbohydrates into soluble sugars, resulting in higher accumulation of total sugars in the fruit (Selvaraj *et al.*, 1989). This result is in conformity with the results achieved by Venkatesan and Tamilmani (2014), Alam *et al.*, (2018) in cape gooseberry, Kacha *et al.*, (2012) in phalsa and Biswas *et al.*, (1988) in guava.

Reducing sugars (%)

Highest reducing sugar content of 3.54% was recorded with ethrel @ 200 ppm (T_3), which was statistically on par with KNO_3 @ 1% (T_5) (3.23%). This was followed by NAA @ 20 ppm (T_1) with 3.26%, KH_2PO_4 @ 1% (T_6) with 3.17%, and cycocel @ 1% (T_4) which registered 3.09%. The lowest reducing sugar content was obtained in the control (T_9), which recorded 2.15%. The enhancement in reducing sugars can be linked to the ability of ethrel to increase invertase and amylase activity which hydrolyze sucrose (a non-reducing sugar) and starch respectively, releasing reducing sugars like glucose and fructose. This metabolic conversion leads to a measurable rise in reducing sugars (Kaur, 2017). Similar results were reported by Venkatesan and Tamilmani (2014), Alam *et al.*, (2018) in cape gooseberry, Kacha *et al.*, (2012) in phalsa and Sandhu and Bal (1989) in ber.

Non-reducing sugars (%)

The maximum non-reducing sugars of 8.48% were recorded with ethrel @ 200 ppm (T3), which was on par with KH_2PO_4 @ 1% (T6) (8.39%), KNO_3 @ 1% (T5) (8.29%) and cycocel @ 1% (T4) (8.22%). This was followed by salicylic acid @ 100 ppm (T2) with 8.09%. The lowest values were obtained in the control (T9) which recorded 7.83%. The increase in non-reducing sugars with ethrel application may be linked to its ability to stimulate the hydrolysis of starch into sucrose, which is the principal non-reducing sugar.

Conclusion

Foliar spray of KNO_3 @ 1% during second fortnight of September and first fortnight of November significantly enhanced postharvest quality by extending shelf life, enhancing fruit firmness, increasing ascorbic acid content, and reducing physiological weight loss, while ethrel @ 200 ppm proved most effective in improving TSS, brix acid ratio, carotenoid content, and sugar compositions.

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