Influence of chemicals and plant bioregulators application during the time of fruit developmental phenophase on fruit weight, quality and shelf-life of Mango (*Mangifera indica.* L).

Abstract

The present study was conducted to know the influence of chemicals and plant bioregulators application during the time of fruit developmental phenophase on fruit weight, quality and shelf-life of Mango (*Mangifera indica.* L) at the fruit research station, Aswaraopet, Telangana, India during the 2022- 23.Among chemicals and plant bioregulators maximum fruit retention percentage (16.851 %), TSS (14.901 ^{0}Brix), total sugars (12.999 %) andshelf life (15.034 days) were recorded with pre-harvest application of CPPU. Maximum ascorbic acid content (49.838 mg. 100 g^{-1}), reducing sugars (4.277 %) and firmness (5.866 $kg.cm^{-2}$) were recorded with pre-harvest application of $Ca(NO_3)_2$ whereas, minimum physiological loss in weight was recorded with the application of CPPU on 12th day (16.244 %). Among different time of chemicals and plant bio regulator application, maximum fruit retention percentage were recorded with chemicals and plant bio regulator applied at 703 phenophase, maximum shelf-life was recorded with the application of CPPU at 709 phenophase, minimum physiological loss in weight was recorded with the application of CPPU at 709 phenophase.

Keywords: Phenophase, chemicals, plant bioregulators, shelf life and quality

Introduction

Mango *(Mangifera indica* L.) belongs to the family Anacardiaceae and order Sapindales. It is native to South and Southeast Asia. It is a popular fruit crop because of its excellent taste, high palatability, precious flavour, aroma and nutritive value it is called the King of fruits. Mango is being grown in more than 87 countries of the world and India ranks first in the world with 2.293 million hectares of area and 2.079 M MT of production (NHB 2019).Telangana is the fourth largest mango-producing state of India and occupies an area of 0.129 million hectares with a production of 1.165 M MT (Horticulture Department, Telangana State 2021-2022).

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Climatic factors, *viz*., rainfall, temperature and sunshine affect the vegetative growth, flowering, fruit set, fruit growth and fruit quality of mango (Davenport, 2007).The influence of climate shift, early and delayed flowering is a characteristic feature of mango (Rajan *et al*. 2011). Rains during the pre-flowering and flowering period lead to delayed flowering and increase vegetative growth in mango (Naidu *et al*. 2018).Despite a shift in mango flowering period as a result of sufficient heat units during the time of fruit maturity phenophase could be the reason for little or unvarying in time of fruit harvesting, which resulted in under sized fruits with poor/ improper fruit quality (Balavardhan and Singh, 2022).Under such circumstances, understanding of fruit growth behaviour by studying fruit phenology during fruit growth and development thereby improvement of fruit quality by accelerating the fruit growth rate through spraying of different plant bio regulators and chemicals at different fruit development phenophases is one of the best alternatives to mitigate the adverse climate effect on mango.

Various plant bio regulators application has been standardized for enhancing the fruit quality by accelerating the fruit growth rate of mango to suit adverse climatic conditions*viz.*,Calcium chloride,calcium nitrate, potassium nitrate and CPPU. Considering the above facts, the present study was carried out to find out the influence of chemicals and plant bioregulators application during the time of fruit developmental phenophase on fruit weight, quality and shelf-life of mango.

Keeping the above information in view, the present investigation was proposed with the following objectives:

1) To know the effect of different chemicals, plant bio regulators on fruit growth, yield and quality of mango cv. Banganpalli.
2) To standardize the time of application of different chemicals, plant bio regulators to improve the fruit growth and quality of mango.

Materials and methods

The present investigation was carried out during 2022-23 at the Fruit Research Station, Aswaraopet, Telangana. Twelve years old, well-grown, uniform-statured trees of mango cv. Banganpalli were selected for the experiment.Two grams of calcium chloride ($CaCl_2$) was dissolved in 100 ml of water to get 2% of $CaCl_2$.Two grams of calcium nitrate $Ca(No_3)_2$ was dissolved in 100 ml of water to get 2% of $Ca(No_3)_2$.One gram of potassium nitrate (KNO_3) was dissolved in 100 ml of water to get 1 % KNO_3.Ten milligrams of CPPU was dissolved in 1 L of water to get a 10 ppm CPPU concentration.The above-mentionedchemicals and plant bioregulators were sprayed to observe the biochemical and physiological parameters of the fruit.

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The percentage of total soluble solids (TSS) was determined using 'Erma hand refractometer and expressed as percent TSS(^{0}Brix).Ascorbic acid was estimated by the procedure elicited by Ranganna (1986). Ten grams of fruit tissue was blended in 3% metaphosphoric acid and the volume was made up to 100 ml of H_3PO_4. The contents were filtered through Whatman No.1 filter paper and 10 ml of the aliquot was taken and titrated with standard dye (2,6-dichlorophenol- indophenol dye) to a pin endpoint. The ascorbic acid was expressed as mg ascorbic acid/ 100 g.Total sugars were determined by Lane and Eynon's (AOAC, 1965) method. The clarified lead-free solution (50 ml) was taken into a 250 ml volumetric flask and to it 10 ml of HCl was added, mixed well and allowed to stand at room temperature for 24 hours. The solution after 24 hours was neutralized with NaOH using a drop of phenolphthalein as an indicator and volume was made up. The solution was taken into a burette and titration was carried out against standard Fehling's solution mixture of A and B (1:1) using methylene blue as an indicator and taking brick red colour as an endpoint.

$$\text{Total sugars (\%)} = \frac{\text{Factor value} \times \text{Dilution } 100}{\text{Titre value} \times \text{Weight of sample (g)} \times \text{Aliquot taken (ml)}}$$

Reducing sugars were determined by Lane and Eynon's (AOAC, 1965) method. Ten grams of fruit pulp was taken and ground well and transferred to a 250 ml volumetric flask, 100 ml of water was added. Two ml of lead acetate solution (45%) was added and kept for 10 minutes for precipitation of colloidal matter. Potassium oxalate (22%) of 2 ml was added to remove the excess lead and the volume was made up to 250 ml and filtered through Whatmann No. 4 filter paper. The lead-free solution was filled into a burette and titrated against 10 ml of standard Fehling's solution mixture of A and B (1:1) using methylene blue as an indicator till the end point was indicated by the formation of a brick red precipitate. The titration was carried out by keeping the Fehling's solution boiling on the heating mantle. The results were expressed as percent reducing sugar.

$$\text{Reducing sugars(\%)} = \frac{\text{Factor value} \times \text{Dilution} \times 100}{\text{Titre value} \times \text{Weight of sample (g)}}$$

The weight of the fruit was recorded on the day of analysis and subtracted from the initial weight taken at the time of harvest. The loss of weight in grams in relation to initial weight was calculated and expressed as percentage.

$$\text{PLW (\%)} = \frac{(\text{Initial weight (g)} - \text{weight after storage (g)} \times 100}{}$$

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Initial weight (g)

Fruit firmness at random was measured on three fruits from each replicate by measuring the penetration force with a penetrometer (Deccan Techno Corporation, 0-20 kg) equipped with a probe of 8.0 mm diameter and expressed in kg cm^2).The shelf life was determined by recording the number of days the fruitsremained in good condition without spoilage in each replication during storage.When the fruit reached a stage that is unsuitable for marketing, it was considered as the end of shelf life which was judged by visual scoring.

Results and discussion

The results offruit retention after the application of different chemicals are presented in the Table 1. The data revealed that there is a significant difference among the application of different chemicals and plant bioregulators during fruit developmental phenophase with respect to fruit retention. Maximum fruit retention(%) was noticedwith the application of CPPU (B_4) (16.851) compared to control and other treatments. Minimum fruit retention(%) was noticed with untreated control (B_0) (11.400).The beneficial effect on increasing fruit set, and decreasing fruit drop may be due to the improving effect of CPPU application on the nutrition status of the trees reflected on increasing fruit set and fruit retention (Pujari *et al*. 2016).A similar increase in fruit retention with CPPU was earlier reported by Ajay Kumar *et al*. (2013) in apple cv. Royal delicious with the application of CPPU at 10 mm fruit size.

The time of application of different chemicals and plant bioregulators during fruit developmental phenophasesignificantly influenced thefruit retention (%) of mango cv. Banganpalli. Maximum fruit retention was noticed with chemicals and plant bioregulators applied at 703 phenophase (T_1) (14.171) which was on par with chemicals and plant bioregulators applied at 705 phenophase (T_2) (13.959) and lowest with chemicals and plant bioregulators applied at 709 phenophase (T_3) (13.522). Abscission of premature fruits in mango is a natural mechanism (Lam *et al*. 1985; Singh, 1960), which is particularly high (90% fruit shedding) during the first 3 to 4 weeks after pollination (Nunez-Elisea and Davenport, 1986; Singh, 1960). The application of chemicals like CPPU at an early stage improved fruit retention by reducing the fruit drop percentage.These results were in accordance with those obtained by Ajay Kumar *et al*. (2013) in apple cv. Royal deliciouswith the application of CPPU at 10 mm fruit size, El-Sabagh (2002) on apple trees and Guirguis *et al*, (2003) on pear trees.

The interaction effect betweendifferent chemicals, plant bioregulators and their time of application onfruit retention was significant. Maximum fruit retention was recorded with

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the application of CPPU at 703 phenophase (B_4T_1) (17.533) which was on par with application of CPPU at 705 phenophase (B_4T_2) (17.000). Minimum fruit retention was recorded with control at 703 phenophase (B_0T_1) (11.000). The application of CPPU during 703 phenopnhase (T_1) increases the fruit retention synergistically compared to their individual application and control as the fruit growth rate was increased during the 703 phenophase.The beneficial effect on increasing fruit set, fruit retention, and decreasing fruit drop may be due to the improving effect of CPPU application on the nutrition status of the trees reflected on increasing fruit set and fruit retention (Pujari *et al*. 2016).These results were in accordance with those obtained by Ajay Kumar *et al*. (2013) in apple cv. Red deliciouswith the application of CPPU at 10 mm fruit size, El-Sabagh (2002) on apple trees and Guirguis *et al*, (2003) on pear trees.

Table 1. Influence of chemicals and plant bioregulators application during the fruit developmental phenophase on fruit retention (%) of mango cv. Banganpalli:

Time of spray / Chemicals, Plant bioregulators	T_1- 703 Phenophase	T_2- 705 Phenophase	T_3- 709 Phenophase	Mean
B_1- $CaCl_2$ @ 2%	14.700^{c}	14.197^{d}	14.010^{d}	**14.302^{b}**
B_2- $Ca(NO_3)_2$ @ 2%	15.200^{c}	14.400^{d}	14.400^{d}	**14.667^{b}**
B_3- KNO_3 @ 1%	12.400^{e}	12.200^{e}	12.000^{e}	**12.200^{c}**
B_4- CPPU @ 10 ppm	17.533^{a}	17.000^{a}	16.000^{b}	**16.851^{a}**
B_0- Control	11.000^{f}	12.000^{e}	11.200^{f}	**11.400^{d}**
Mean	**14.171^{a}**	**13.959^{a}**	**13.522^{b}**	

Factors	F – Test	SE(m)±	CD at 5 %
Factor B	*	0.136	0.397
Factor T	*	0.106	0.308
Factor B × T	*	0.236	0.688

Table 2. Influence of chemicals and plant bioregulators application during the fruit developmental phenophase on TSS(^{0}Brix) of mango cv. Banganpalli:

Time of spray / Chemicals, Plant bioregulators	T_1- 703 Phenophase	T_2- 705 Phenophase	T_3- 709 Phenophase	Mean
B_1- $CaCl_2$ @ 2%	14.400^{d}	12.700^{e}	15.900^{c}	**14.333^{b}**
B_2- $Ca(NO_3)_2$ @ 2%	12.157^{f}	16.100^{b}	16.300^{b}	**14.852^{a}**
B_3- KNO_3 @ 1%	14.503^{d}	16.497^{b}	12.900^{e}	**14.633^{a}**
B_4- CPPU @ 10	12.700^{e}	17.300^{a}	14.703^{d}	**14.901^{a}**

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ppm				
B_0- Control	12.300^{f}	11.900^{f}	11.703^{g}	**11.968^{c}**
Mean	**13.212^{c}**	**14.899^{a}**	**14.301^{b}**	

Factors	**F – Test**	**SE(m)±**	**CD at 5 %**
Factor B	*	0.108	0.314
Factor T	*	0.084	0.244
Factor B × T	*	0.187	0.545

The results on TSS (^{0}Brix) of fruits after the application of different chemicals and plant bioregulators during fruit developmental phenophase are presented in Table 2. The data revealed that there is a significant difference among chemicals and plant bioregulators with respect to the TSS of fruits. Maximum TSS was noticed with CPPU (B_4) (14.901) which was on par with the application of $Ca(NO_3)_2(B_2)$)(14.852) and $KNO_3(B_3)$ (14.633) however lowest TSS was noticed with control (B_0) (11.968).The higher TSS content with CPPU application might be attributed to a higher rate of photosynthates assimilation, as cytokinin is known to influence sink-source relations by mobilization of metabolites and nutrients to the developing fruits (Banyal and Banyal, 2020).The results are in accordance with that ofBarkule*et al*. (2018) who observed higher TSS content in sapota in Kallipati when treated with 6 ppm CPPU.

The time of application of different chemicals and plant bioregulators during fruit developmental phenophasesignificantly influenced the TSS.Maximum TSS was noticed with 705 phenophase (T_2) and lowest with 703 phenophase (T_1). The application of chemicals at an early stage helps in reducing the acid content in the fruits and increases the TSS. These findings obtained in the present investigation can be compared to those obtained byBanyal and Banyal, (2020) in kiwi cv. Hayward when treated with CPPU at petal fall.

A significant difference was observed in the interaction effect betweendifferent chemicals, plant bioregulators and their time of application with respect to TSS in fruits. Maximum TSS was noticed with the application of CPPU at 705 phenophase (B_4T_2) (17.300) compared to control and other treatments however the lowest TSS was noticed with control at 709 phenophaseB_0T_3(11.703).The higher TSS content with CPPU application might be attributed to a higher rate of photosynthates assimilation, as cytokinin is known to influence sink-source relations by mobilization of metabolites and nutrients to the developing fruits (Banyal and Banyal, 2020).The application of CPPU during the 705 phenopnhase (T_2) increases TSS synergistically compared to their individual application and control.The reason might be due to the production of a higher

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number of leaves with much more amount of chlorophyll content which produces more metabolites by the photosynthesis process and the accelerated flow of photosynthetic products (mainly carbohydrates) towards fruits resulted by CPPU foliar spray. These carbohydrates mainly contain sugar as major part of soluble solids and due to source to sink relationship, a higher percentage of total sugar may be found in treated fruits. These findings obtained in the present investigation can be compared to those obtained byBanyal and Banyal, (2020) in kiwi cv. Hayward when treated with CPPU at petal fall and Barkule*et al*. (2018) who observed higher TSS content in sapota in Kallipati when treated with 6 ppm CPPU 30 days before harvest.

The results on ascorbic acid ($mg.100^{-1}$)of fruits after the application of different chemicals and plant bioregulators during fruit developmental phenophase are presented in the Table 3.The data revealed that there is a significant difference among chemicals and plant bioregulators with respect to ascorbic acid contentin fruits. Maximum ascorbic acid content was noticed with $Ca(NO_3)_2(B_2)$ (49.838) compared to control and other treatments. However,the lowest ascorbic acid content was noticed with control (B_0) (38.002).The oxidizing enzymes like ascorbic acid oxidase, peroxidase, catalase and polyphenol oxidase might be causing a decrease in the ascorbic acid content of fruits (Mapson 1970; Singh *et al*. 2005). Activities of oxidizing enzymes might be reduced in $Ca(NO_3)_2$ treated fruits resulting in higher ascorbic acid.(Goutam *et al*. 2010).This finding is in agreement with that reported by Goutam *et al*. (2010) in $Ca(NO_3)_2$ treated fruits of guava cv. Allahabad safedaat colour break stage of the fruit.

The time of application of different chemicals and plant bioregulators during fruit developmental phenophasesignificantly influenced the ascorbic acid content in fruits.Maximum ascorbic acid content was noticed with 709 phenophase (T_3) (46.199) which was on parwith 705 phenophase (T_2) (46.122) and lowest with 703 phenophase (T_1) (42.234).This finding is in agreement with that reported by Goutam *et al*. (2010) in guava cv. Allahabad safedaat colour break stage of fruit.

A significant difference was observed in the interaction effect betweendifferent chemicals, plant bioregulators and their time of application with respect to ascorbic acid content in fruits. Maximum ascorbic acid content was noticed with the application of$Ca(NO_3)_2$at 703 phenophase (B_2T_1) (50.013) which was on par withthe application of$Ca(NO_3)_2$at 705 phenophase (B_2T_2)(50.003), with the application of$CaCl_2$at 705 phenophase(B_1T_2) (49.497),withthe application of$Ca(NO_3)_2$at 709 phenophase(B_2T_3) (49.503), withthe application of CPPUat 709 phenophase(B_4T_3)(49.090) and with the application of$CaCl_2$at 709 phenophase(B_1T_3) and (49.000) however the lowest ascorbic acid content was noticed with the control at 703 phenophase (B_0T_1) (35.770).

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Shokrollahfam*et al*. (2012) and Veltman *et al*. (2000) reported that calcium compounds bind with membrane and increase its stability, therefore, they prevent free radicals and reactive oxygen species from connecting to membrane and contribute to the maintenance of the health of biological membranes. The present findings are in agreement with those reported by (Zeraatgar*et al*. 2018) in jujube with the application of$Ca(NO_3)_2$at three intervals uptocolour change.

Table 3. Influence of chemicals and plant bioregulators application during the fruit developmental phenophase on Ascorbic acid (mg. 100 g^{-1}) of mango cv. Banganpalli:

Time of spray Chemicals, Plant bioregulators	T_1- 703 Phenophase	T_2- 705 Phenophase	T_3- 709 Phenophase	Mean
B_1- $CaCl_2$ @ 2%	41.103^{c}	49.503^{a}	49.000^{a}	**46.536^{b}**
B_2- $Ca(NO_3)_2$ @ 2%	50.013^{a}	50.003^{a}	49.497^{a}	**49.838^{a}**
B_3- KNO_3 @ 1%	44.263^{b}	45.047^{b}	45.210^{b}	**44.840^{c}**
B_4- CPPU @ 10 ppm	40.020^{c}	46.017^{b}	49.090^{a}	**45.042^{c}**
B_0- Control	35.770^{e}	40.040^{c}	38.197^{d}	**38.002^{d}**
Mean	**42.234^{b}**	**46.122^{a}**	**46.199^{a}**	

Factors	F – Test	SE(m)±	CD at 5 %
Factor B	*	0.462	1.345
Factor T	*	0.358	1.042
Factor B × T	*	0.800	2.330

The results on the total sugar content of fruits after the application of different chemicals and plant bioregulators during fruit developmental phenophase are presented in the Table 4.The data revealed that there is a significant difference among chemicals and plant bioregulators with respect to total sugarcontentin fruits. Maximum total sugarcontent was noticed with CPPU (B_4) (12.999) compared to control and other treatments. However, the lowest total sugar content was noticed with control (B_0) (10.093).The higher sugar content with CPPU may be due to the increased assimilation of photosynthates, as cytokinin affects the mobilization of metabolites and nutrients to the treated portion of the plant(Leopold and Kriedemann, 1975). Due to increased leaf production with higher chlorophyll content, which results in more metabolites produced during photosynthesis, and quicker photosynthetic product flow (mostly carbohydrates) towards fruits as a result of CPPU foliar spray. Due to the source-to-sink relationship, sugar makes up the majority of the soluble solids in these carbs, which results in a larger percentage of total soluble solids (Barkule*et al*. 2018).The present findings are in agreement with those reported by Barkule*et al*. (2018) in sapota cv. Kalipatti with CPPU application

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The time of application of different chemicals and plant bioregulators during fruit developmental phenophasesignificantly influenced the total sugar content in fruits.Maximum total sugarcontentwas noticed with 703 phenophase (T_1) (11.655) and lowest with 709 phenophase (T_3) (10.831).Due to increased leaf production with higher chlorophyll content, which results in more metabolites produced during photosynthesis, and quicker photosynthetic product flow (mostly carbohydrates) towards fruits as a result of CPPU foliar spray. Due to the source-to-sink relationship, sugar makes up the majority of the soluble solids in these carbs, which results in a larger percentage of total soluble solids (Barkule*et al*. 2018).The present findings are in agreement with those reported by Barkule*et al*. (2018) in sapota cv. Kalipatti with CPPU application.

Table 4. Influence of chemicals and plant bioregulators application during the fruit developmental phenophase on total sugars (%) of mango cv. Banganpalli:

Time of spray / Chemicals, Plant bioregulators	T_1- 703 Phenophase	T_2- 705 Phenophase	T_3- 709 Phenophase	Mean
B_1- $CaCl_2$ @ 2%	11.697^{c}	11.010^{d}	10.020^{e}	**10.909^{c}**
B_2- $Ca(NO_3)_2$ @ 2%	12.217^{b}	11.100^{d}	11.140^{c}	**11.486^{b}**
B_3- KNO_3 @ 1%	10.900^{d}	11.517^{c}	10.100^{e}	**10.839^{c}**
B_4- CPPU @ 10 ppm	13.400^{a}	12.897^{a}	12.700^{b}	**12.999^{a}**
B_0- Control	10.063^{e}	10.020^{e}	10.197^{e}	**10.093^{d}**
Mean	**11.655^{a}**	**11.309^{b}**	**10.831^{c}**	

Factors	F – Test	SE(m)±	CD at 5 %
Factor B	*	0.112	0.326
Factor T	*	0.087	0.252
Factor B × T	*	0.194	0.564

A significant difference was observed in the interaction effect betweendifferent chemicals, plant bioregulators and their time of application with respect toTotal sugar content in fruits. Maximum total sugars content was noticed with the application of CPPU at 703 phenophase (B_4T_1) (13.400) which was on par withthe application of CPPU at 705 phenophase (B_4T_2) (12.897) however the lowest total sugars contentwas noticed withB_0T_2(10.020). The reason might be due to the production of a higher number of leaves with much more amount of chlorophyll content which produces more metabolites by the photosynthesis process and the accelerated flow of photosynthetic products (mainly carbohydrates) towards fruits resulted by CPPU foliar spray. Thesecarbohydrates mainly contain sugar as a major part of soluble solids and due to source to sink relationship, a higher percentage of total sugar may be found in treated fruits. The present

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findings are in agreement with those reported by Barkule*et al*. (2018) in sapota cv. Kalipatti with CPPU application at 30 days before harvest.

The results on reducing sugars (%)of fruits after the application of different chemicals and plant bioregulators during fruit developmental phenophase are presented in the Table 5.The data revealed that there is a significant difference among chemicals, plant bio regulators with respect to reducingsugarcontentin fruits. Maximum reducing sugars content was noticed with $Ca(NO_3)_2(B_2)$ (4.277) compared to control and other treatments. However, the lowest reducing content was noticed with control (B_0) (3.279). Calcium or nitrogen elements might be involved in hydrolytic enzyme activation which leads to the conversion of carbohydrates into simple sugars (Sankar *et al*. 2013).The present findings are in agreement with those reported by Vidya *et al*. (2014) in mango cv. Mallika with application of $Ca(NO_3)_2$at 20 days before harvest.

The time of application of different chemicals and plant bioregulators during fruit developmental phenophasesignificantly influenced the reducing sugar content in fruits.Maximum reducing sugarcontentcontentwas noticed with 703 phenophase (T_1) (4.063) and lowest with 709 phenophase (T_3) (3.755).Calcium helps in faster conversion of metabolites to simple sugars and increases the sugars, helps in reducing the acid towards fruit maturity and increases the reducing sugar content.The present findings are in agreement with those reported by Vidya *et al*. (2014) in mango cv. Mallika with application of $Ca(NO_3)_2$at 20 days before harvest.

A significant difference was observed in the interaction effect betweendifferent chemicals, plant bioregulators and their time of application with respect to reducing sugars content in fruits. Maximum reducing sugar content was noticed with the application of$Ca(NO_3)_2$at 703 phenophase (B_2T_1) (4.440) which was on par with the application of CPPU at 703 phenophase (B_4T_1) (4.257) however the lowest reducingsugar contentwas noticed withB_0T_2 (3.040). The application of $Ca(NO_3)_2$during the fruit developmental phenophaseincreases reducingsugar content synergistically compared to their individual application and control.Calcium helps in faster conversion of metabolites to simple sugars and increases the sugars, helps in reducing the acid towards fruit maturity and increases the reducing sugar content.The present findings are in agreement with those reported by Vidya *et al*. (2014) in mango cv. Mallika with application of $Ca(NO_3)_2$at 20 days before harvest.

Table 5. Influence of chemicals and plant bioregulators application during the fruit developmental phenophase on reducing sugars (%) of mango cv. Banganpalli:

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Time of spray Chemicals, Plant bioregulators	T_1- 703 Phenophase	T_2- 705 Phenophase	T_3- 709 Phenophase	Mean
B_1- $CaCl_2$ @ 2%	4.217^{b}	4.147^{b}	4.183^{b}	**4.182^{b}**
B_2- $Ca(NO_3)_2$ @ 2%	4.440^{a}	4.200^{b}	4.190^{b}	**4.277^{a}**
B_3- KNO_3 @ 1%	3.803^{d}	3.500^{e}	3.697^{d}	**3.667^{d}**
B_4- CPPU @ 10 ppm	4.257^{a}	4.017^{c}	3.503^{e}	**3.926^{c}**
B_0- Control	3.597^{e}	3.040^{g}	3.200^{f}	**3.279^{e}**
Mean	**4.063^{a}**	**3.781^{b}**	**3.755^{b}**	

Factors	F – Test	SE(m)±	CD at 5 %
Factor B	*	0.030	0.086
Factor T	*	0.023	0.067
Factor B × T	*	0.051	0.150

All the chemicals and plant bioregulators have significantly minimized the PLW (%) presented in Table. 6 over control during the storage period.Physiological weight loss is a continuous phenomenon during storage caused due to moisture loss. Moisture loss through respiration and transpiration during storage which affects the net weight and eventually the fruit becomes unsalable as a result of shrinking (Salunkhe, 1984). The endogenous ethylene production rate was reduced when Japanese pear fruits were sprayed with CPPU which resulted in delayed ripening. These are the possible reasons behind the minimization of physiological loss of weight. .It might be due to anti senescence role of CPPU which lowered rate of respiration and retard the activity of enzymes responsible to ripening which slow down process of senescence and deterioration to extend shelf life. The present findings are in agreement with those reported by Barkule*et al.* (2018) in sapota cv. Kalipattiwith application of CPPU at 30 days before harvest.

The time of application of different chemicals and plant bioregulators significantly influenced thePLW (%) of fruits.Minimum PLW (%) of fruit was noticed with 709 phenophase (T_3).It might be due to anti senescence role of CPPU which lowered rate of respiration and retard the activity of enzymes responsible to ripening which slow down process of senescence and deterioration to extend shelf life. The present findings are in agreement with those reported by Barkule*et al.* (2018) in sapota cv. Kalipattiwith application of CPPU at 30 days before harvest.

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Table 6. Influence of chemicals and plant bio regulators application during the time of fruit developmental phenophase on physiological loss in weight (%) of mango cv. Banganpalli:

Treatment	PLW (%)				PLW (%)			
Days	3rd Day				6th Day			
	T_1	T_2	T_3	Means	T_1	T_2	T_3	Means
B_1	5.590[d]	5.410[e]	5.200[e]	**5.400[c]**	12.447[c]	12.200[c]	12.270[c]	**12.306[b]**
B_2	5.597[d]	5.193[e]	4.970[d]	**5.253[c]**	12.600[b]	12.150[c]	11.700[d]	**12.150[c]**
B_3	6.023[c]	5.697[d]	5.297[e]	**5.672[b]**	13.100[b]	12.500[c]	12.003[c]	**12.534[b]**
B_4	5.290[e]	4.900[f]	4.700[f]	**4.963[d]**	10.803[e]	11.197[d]	10.923[e]	**10.974[d]**
B_0	9.200[b]	9.193[b]	9.597[a]	**9.330[a]**	14.700[a]	12.200[c]	12.500[c]	**13.133[a]**
Means	**6.340[a]**	**6.079[b]**	**5.953[c]**		**12.730[a]**	**12.049[b]**	**11.879[c]**	
Factors	F – Test	SE(m)±		CD	F – Test	SE(m)±		CD
Factor B	*	0.053		0.154	*	0.106		0.309
Factor T	*	0.041		0.119	*	0.082		0.239
B × T	*	0.091		0.266	*	0.184		0.535
Factors	F – Test	SE(m)±		CD	F – Test	SE(m)±		CD
Factor B	*	0.099		0.289	*	0.130		0.378
Factor T	*	0.077		0.224	*	0.100		0.293
B × T	*	0.172		0.501	*	0.225		0.654

B_1-$CaCl_2$, B_2-$Ca(NO_3)_2$, B_3- KNO_3, B_4- CPPU T_1- 703 Phenophase, T_2- 705 Phenophase, T_3- 709 Phenophase

Treatment	PLW (%)				PLW (%)			
Days	9th Day				12th Day			
	T_1	T_2	T_3	Means	T_1	T_2	T_3	Means
B_1	14.903[c]	15.400[c]	14.600[d]	**14.968[c]**	17.203[e]	17.600[e]	17.800[d]	**17.534[d]**
B_2	15.267[c]	15.737[b]	14.043[e]	**15.016[c]**	18.200[d]	18.297[d]	18.363[d]	**18.287[c]**
B_3	16.100[b]	15.700[b]	15.400[c]	**15.733[b]**	19.053[c]	19.980[b]	20.000[b]	**19.678[b]**
B_4	13.020[f]	14.000[e]	12.893[f]	**13.304[d]**	14.500[f]	16.533[f]	17.700[e]	**16.244[e]**
B_0	18.867[a]	18.767[a]	18.833[a]	**18.822[a]**	22.700[a]	22.900[a]	22.397[a]	**22.666[a]**
Means	**15.631[b]**	**15.921[a]**	**15.154[c]**		**18.331[b]**	**19.062[a]**	**19.252[a]**	

B_1-$CaCl_2$, B_2-$Ca(NO_3)_2$, B_3- KNO_3, B_4- CPPU T_1- 703 Phenophase, T_2- 705 Phenophase, T_3- 709 Phenophase

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Table 7. Influence of chemicals and plant bio regulators application during the time of fruit developmental phenophase on fruit firmness (kg cm^{-2}) of mango cv. Banganpalli:

Treatment	Firmness (Kg cm^{-2})				Firmness (Kg cm^{-2})			
Days	3rd Day				6th Day			
	T_1	T_2	T_3	Means	T_1	T_2	T_3	Means
B_1	9.697[c]	9.203[d]	9.270[d]	**9.390[c]**	6.500[d]	6.203[d]	6.370[c]	**6.358[b]**
B_2	11.800[a]	12.100[a]	11.900[a]	**11.933[a]**	7.500[b]	8.500[a]	8.500[a]	**8.167[a]**
B_3	7.200[f]	7.800[e]	7.400[f]	**7.467[d]**	6.600[c]	6.500[c]	5.800[e]	**6.300[b]**
B_4	11.397[b]	11.597[b]	11.897[a]	**11.630[b]**	5.060[g]	5.400[f]	5.087[g]	**5.182[c]**
B_0	6.400[g]	7.200[f]	7.897[e]	**7.166[d]**	4.070[i]	5.400[f]	4.700[h]	**4.723[d]**
Means	**9.299[b]**	**9.580[a]**	**9.673[a]**		**5.946[c]**	**6.401[a]**	**6.091[b]**	
Factors	F – Test	SE(m)±		CD	F – Test	SE(m)±		CD
Factor B	*	0.076		0.222	*	0.058		0.168
Factor T	*	0.059		0.172	*	0.045		0.130
B × T	*	0.132		0.384	*	0.100		0.291
Factors	F – Test	SE(m)±		CD	F – Test	SE(m)±		CD
Factor B	*	0.044		0.128	*	0.023		0.066
Factor T	*	0.034		0.099	*	0.018		0.051
B × T	*	0.076		0.221	*	0.039		0.114

B_1-$CaCl_2$, B_2-$Ca(NO_3)_2$, B_3- KNO_3, B_4- CPPU T_1- 703 Phenophase, T_2- 705 Phenophase, T_3- 709 Phenophase

Treatment	Firmness (Kg cm^{-2})				Firmness (Kg cm^{-2})			
Days	9th Day				12th Day			
	T_1	T_2	T_3	Means	T_1	T_2	T_3	Means
B_1	4.587[f]	4.620[f]	4.600[f]	**4.602[c]**	4.267[f]	4.197[g]	4.087[h]	**4.183[c]**
B_2	5.800[c]	6.723[a]	6.400[b]	**6.308[a]**	5.200[c]	6.600[a]	5.797[b]	**5.866[a]**
B_3	4.057[g]	4.497[f]	4.090[g]	**4.214[d]**	4.010[h]	4.100[h]	4.047[h]	**4.052[d]**
B_4	5.400[d]	5.697[c]	4.900[e]	**5.332[b]**	4.800[d]	4.900[d]	4.500[e]	**4.733[b]**
B_0	3.073[i]	4.400[f]	3.703[h]	**3.726[e]**	3.040[j]	3.897[i]	3.097[j]	**3.344[e]**
Means	**4.583[c]**	**5.187[a]**	**4.739[b]**		**4.263[b]**	**4.739[a]**	**4.305[b]**	

B_1-$CaCl_2$, B_2-$Ca(NO_3)_2$, B_3- KNO_3, B_4- CPPU T_1- 703 Phenophase, T_2- 705 Phenophase, T_3- 709 Phenophase

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Among interactions CPPU and Ca treatmentsapplied at 709 phenophasehave reduced the PLW (%) synergistically over control and their individual application.It might be due to anti senescence role of CPPU which lowered rate of respiration and retard the activity of enzymes responsible to ripening which slow down process of senescence and deterioration to extend shelf life. The present findings are in agreement with those reported by Barkule*et al*. (2018) in sapota cv. Kalipattiwith application of CPPU at 30 days before harvest.

Fruit firmness presented in Table.7 indicated a significant reduction during ripening reflecting the rapid softening of pulp. This may be due to changes in the amount of pectin materials cementing the cell walls and the hydrolysis of starch and hemicelluloses in the fruit (Rao *et al*. 1971). Further, the firmness indicates the progression of ripening in climacteric fruits. Among chemicals and plant bioregulators, $Ca(NO_3)_2$ has recorded more firmness during storage over control and other treatments. As earlier discussed, by the application of calcium may be attributed to its consistency in the cell wall resulting in fruit firmness, retardation of respiratory rate and delay in senescence (Singh *et al*. 1993). Martinsson *et al*. (2006) also observed that the application of calcium nitrate in Elsanta Strawberry contributed to more firmness of the fruits. Present results were strongly confirmed by the findings of Bisen*et al*. (2012) in guava cv. Allahabad Safedawith application of Ca $(NO_3)_2$at 20 days before harvest.

The time of application of different chemicals and plant bioregulators significantly influenced the firmnessof fruits. Maximumfruit firmness was noticed with 705 phenophase (T_2).Calcium is essential for the firmness of cell membrane systems on which the fundamental integrity of the cell metabolism is dependent.Present results were strongly confirmed by the findings of Bisen*et al*. (2012) in guava cv. Allahabad Safedawith application of Ca $(NO_3)_2$at 20 days before harvest.

Among interactions Ca $(NO_3)_2$applied at 705 phenophasehave reduced the firmness($kg.cm^{-2}$) synergistically over control and their individual application.As earlier discussed, by the application of calcium may be attributed to its consistency in the cell wall resulting in fruit firmness, retardation of respiratory rate and delay in senescence (Singh *et al*. 1993).Martinsson *et al*. (2006) also observed that application of calcium nitrate in Elsanta Strawberry contributed to more firmness of the fruits. Present results were strongly confirmed by the findings of Bisen*et al*. (2012) in guava cv. Allahabad Safedawith application of Ca $(NO_3)_2$at 20 days before harvest.

The results on the shelf life of fruits after the application of different chemicals and plant bioregulators during fruit developmental phenophase are presented in Table .8 The data

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revealed that there is a significant difference between chemicals and plant bio regulators with respect to the shelf life of fruits. Maximum shelf life was noticed with CPPU (B_4) (15.034 days) compared to control and other treatments. However, the lowest shelf life was noticed with control (B_0) (11.156 days). CPPU, which is a synthetic cytokinin, is used to extend the shelf and storage life of fruits, especially in grapes (Marzouk and Kassem, 2011). The increased shelf life with CPPU application might be due to the anti-senescence role of CPPU which lower the rate of respiration and retard the activity of enzymes responsible for ripening which slow down the process of senescence and deterioration thus extending shelf life (Barkule*et al*. 2018). Similar results were obtained by Barkule*et al*. (2018) in sapota cv. Kalipattiwith application of CPPU at 30 days before harvest.

Time of application of different chemicals and plant bioregulators during fruit developmental phenophasesignificantly influenced the shelf life of fruits.Maximum was noticed with 709 phenophase (T_3) (13.549 days) which was on parwith 705 phenophase (T_2) (13.397 days) and lowest with 703 phenophase (T_1) (12.188 days). It might be due to anti senescence role of CPPU which lowered rate of respiration and retard the activity of enzymes responsible to ripening which slow down process of senescence and deterioration to extend shelf life. Similar results were obtained by Barkule*et al*. (2018) in sapota cv. Kalipattiwith application of CPPU at 30 days before harvest.

Table 8. Influence of chemicals and plant bioregulators application during the fruit developmental phenophase on shelf life (days) of mango cv. Banganpalli:

Time of spray Chemicals, Plant bioregulators	**T_1- 703 Phenophase**	**T_2- 705 Phenophase**	**T_3- 709 Phenophase**	**Mean**
B_1- $CaCl_2$ @ 2%	12.100^{e}	12.770^{d}	13.400^{c}	**12.757^{c}**
B_2- $Ca(NO_3)_2$ @ 2%	14.330^{b}	13.420^{c}	13.223^{c}	**13.658^{b}**
B_3- KNO_3 @ 1%	10.603^{f}	13.700^{c}	13.553^{c}	**12.619^{c}**
B_4- CPPU @ 10 ppm	14.403^{b}	15.100^{a}	15.600^{a}	**15.034^{a}**
B_0- Control	9.503^{g}	11.993^{e}	11.970^{e}	**11.156^{d}**
Mean	**12.188^{b}**	**13.397^{a}**	**13.549^{a}**	

Factors	**F – Test**	**SE(m)±**	**CD at 5 %**
Factor B	*	0.121	0.351
Factor T	*	0.093	0.272
Factor B × T	*	0.209	0.608

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A significant difference was observed in the interaction effect betweendifferent chemicals, plant bioregulators and their time of application with respect to the shelf life of fruits. Maximum shelf life was noticed with the application of CPPU at 709 phenophase (B_4T_3) (15.600 days) which was on par with the application of CPPU at 705 phenophase (B_4T_2) (15.100 days) however the lowestshelf life was noticed with control at 703 phenophase (B_0T_1) (9.503). The application of CPPUduring the 709 phenophase (T_3) increases the shelf life of fruits synergistically compared to their individual application and control.It might be due to anti senescence role of CPPU which lowered rate of respiration and retard the activity of enzymes responsible to ripening which slow down process of senescence and deterioration to extend shelf life. The present findings are in agreement with those reported by Barkule*et al*. (2018) in sapota cv. Kalipattiwith application of CPPU at 30 days before harvest.

References

Ajay Kumar, B., Rajeev Raina. and Rajesh Kumar, K. 2013. Improvement in fruit set, retention, weight and yield of apple cv. Royal delicious through foliar application of plant growth regulators. *Journal of Krishi Vigyan*. 2(1): 30-32.

Banyal, A.K. and Banyal, S.K. 2020.Forchlorfenuron (CPPU) a promising plant growth regulator augments fruit size, fruit weight, quality and yield of kiwifruit (*Actinidia deliciosa*) cv. Hayward. *International Journal of Current Microbiology and Applied Sciences.*9(5):2091-2101.

Barkule, S. R., Patel, B. N., Shah, N. and Gurjar, T. 2018. Effect of 28-homobrassinolide, cppu, GA_3 and humic acid on quality and shelf-life of sapota (*Manilkara achras*) cv. Kalipatti harvested in august month.

Bisen, Sharad, R. S. Thakur, and D. Tembhare.2014. "Effect of calcium nitrate and gibberellic acid application on growth, fruit quality and post harvestbehaviour of guava fruit." .*The Ecoscan*. 6. 55-62.

Davenport, T.L. Reproductive physiology of mango. 2007. *Brazilian Journal of Plant Physiology*. 19(4): 363-376, 2007.

UNDER PEER REVIEW

El-Sabagh A. S. 2002. Effect of Sitofex (CPPU) on “Anna” apple fruit set and some fruit characteristics. *Alexandria Journal of Agricultural Research*. 47(3): 85-92.

Guirguis, N. S., Eman, S., Attala, and Ali, M. M. 2003. Effect of Sitofex (CPPU) on fruit set, fruit quality of Le Conte pear cultivar. *Annals of Agricultural ScienceMoshtohor.* 41(1): 271-282.

Goutam M, Dhaliwal H. S., Mahajan, B.V. 2010. Effect of pre-harvest calcium sprays on post-harvest life of winter guava (*Psidium guajava* L.). *Journal of Food Science and Technology*. Oct;47(5):501-6.

L. G. K., Naidu, G., Subbi Reddy, V., Ramamurthy. and T. Prathibha. 2018. *The Andhra Agricultural Journal*.65 (1): 250-252,. Climate Change Induced Abnormal Flowering Pattern in Mango.

Lam, P. F., K. H. Ng, D. Omar and Talib. 1985. Fruit-drop and growth, respiration and chemical changes in ‘Golek’ mango. *Bul. Penyel. Mardi*.13 : 8-14.

Lane, J.H. and Eynon, L. 1965. Determination of reducing sugars by Fehling’s solution with methylene blue indicator. *Journal of Chemical Sciences*. India. 42(2): 31-39.

Leopold, A.C. andKriedemann, P.E. 1975. Plant Growth and Development. 2nd ed. *McGraw-Hill Book Company*, New York.

M.R. Balavardhan and J. Singh. 2022. Effect of heat units and time duration required for maturation of mango (*Mangifera indica L.*): A review. *The Pharma Innovation Journal*. 11(5): 1803-1808.

Mapson CW (1970) Vitamins in fruits: Stability of L-ascorbic acid. In: Biochemistry of fruits and their products. *Academic Press*, London, 376–387.

Martinsson, M., Kwast, A., Cieslinski, G. and Treder, W. 2006. Impact of production systems and fertilizer application on yield and quality of strawberries. *Acta Horticulturae*. 708: 59-64.

UNDER PEER REVIEW

National Horticultural Board. Ministry of Agriculture and Farmer's Welfare. Government of India.

Nunez-Elisea, R. and T. L. Davenport 1986. Abscission of mango fruitlets as influenced by enhanced ethylene biosynthesis. *Plant Physiology*.,82 : 991-994.

Pujari, K.H., Malshe, A.V., Zagade, V.V. and Shedge, M.S. 2016. Effect of swell (CPPU) on fruit retention, fruit quality and yield of "Alphonso" mango. *Plant Archives*. 16(2): 649-653.

Rajan, S., Tiwari, D., Singh, V. K., Saxena, P., Singh, S., Reddy, Y. T. N. and Kennedy, R. 2011. Application of extended BBCH scale for phenological studies in mango (*Mangifera indica* L.). *Journal of Applied Horticulture*., *13*(2), 108-114.

Ranganna, S. 1986. Carbohydrates. In : Handbook of Analysis and Quality Control for Fruit and Vegetable Products. 2nd Ed., Tata McGraw Hills, New Delhi. 5-109.

Rao, V.N., Shanmugavelu, K.G., Srinivas, C. and Padmanabaiah, D.R. 1971. Studies on the effect of ethrel on ripening of fruits. *South Indian Horticulture*. 19:71.

Salunkhe, D.K. 1984. Post harvest biology of fruits vol. II. CRC. *Press INC Bora Rton Florida.*

Sankar, C., Saraladevi, D. and Parthiban, S. 2013. Effect of foliar application of micronutrients and sorbitol on fruit quality and leaf nutrient status of mango cv. Alphonso. *The Asian Journal of Horticulture*.8(2):714-719.

Shokrollahfam, S., Hajilou, J., Zare, F., Tabatabaei, S.J. andNaghshibandhasani, R. 2012. Effects of calcium chloride and salicylic acid on quality traits and storage life of plum cultivar. *Journal of Food Research*. 22(1):75-76

Singh, R.P., Tandon, D.K. and Kalra, S.K. 1993. Changes in post-harvest quality of mangoes affected by pre-harvest application of calcium salts. *Scientia Horticulturae*. 54(3): 211-219.

UNDER PEER REVIEW

Singh, S., Singh, A.K., Joshi, H.K .2005. Prolong storability of Indian gooseberry (*Emblica officinalis* Gaertn.) under semiarid ecosystem of Gujarat. *The Indian Journal of Agricultural Sciences*. 75:647–650.

Singh, U. R. 1960. Studies in the fruit drop of mango (*Mangifera indica* L.). II. Nature and extent of fruit drop. *Advances in Horticultural Science*. 4 : 142-154.

Veltman, R.H., Kho, R.M., Van Schaik, A.C.R., Sanders, M.G., Oosterhaven, J. 2000. Ascorbic acid and tissue browning in pears (*Pyrus communis* L. cvs Rocha and Conference) under controlled atmosphere conditions. *Postharvest Biology and Technology*. 19(2):129-137.

Vidya, A., Swamy, G. S. K., Prakash, N. B., Jagadeesh, R. C., Jagadesh, S. L., Gangadharappa, P. M. and Mukesh, L. C. 2014. Effect of preharvest spray of nutrients on the physico-chemical characters in mango (*Mangifera indica* L.) cv. Mallika. *Mysore Journal of Agricultural. Sciences*. *48*(4), 529-533.

Zeraatgar, H., Davarynejad, G. H., Moradinezhad, F. and Abedi, B. 2018. Effect of salicylic acid and calcium nitrate spraying on qualitative properties and storability of fresh jujube fruit (*Ziziphus jujube* Mill.). *NotulaeBotanicae Horti Agrobotanici Cluj-Napoca*. *46*(1), 138-147.

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