

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 °Brix), total sugars (12.999 %) and shelf 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(NO₃)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.

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Keywords: Phenophase, chemicals, plant bioregulators, shelf life, and fruit 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.

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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 $\text{Ca}(\text{NO}_3)_2$ was dissolved in 100 ml of water to get 2% of $\text{Ca}(\text{NO}_3)_2$. 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-mentioned chemicals and plant bioregulators were sprayed to observe the biochemical and physiological parameters of the fruit.

The percentage of total soluble solids (TSS) was determined using 'Erma hand refractometer and expressed as percent TSS (°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 H₃PO₄. 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.

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

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 cm²). The shelf life was determined by recording the number of days the fruits remained 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 of fruit 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 noticed with the application of CPPU (B₄) (16.851) compared to control and other treatments. Minimum fruit retention (%) was noticed with untreated control (B₀) (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 phenophases significantly influenced the fruit retention (%) of mango cv. Banganpalli. Maximum fruit retention was noticed with chemicals and plant bioregulators applied at 703 phenophase (T₁) (14.171) which was on par with chemicals and plant bioregulators applied at 705 phenophase (T₂) (13.959) and lowest with chemicals and plant bioregulators applied at 709 phenophase (T₃) (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 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 delicious with 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 between different chemicals, plant bioregulators and their time of application on fruit retention was significant. Maximum fruit retention was recorded with

the application of CPPU at 703 phenophase (B₄T₁) (17.533) which was on par with application of CPPU at 705 phenophase (B₄T₂) (17.000). Minimum fruit retention was recorded with control at 703 phenophase (B₀T₁) (11.000). The application of CPPU during 703 phenophase (T₁) 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 ~~delicious~~ Delicious with 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	

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SE: ?
CaCl₂ ?
CPPU? Etc.

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Table 2. Influence of chemicals and plant bioregulators application during the fruit developmental phenophase on TSS(°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

ppm				
B₀- 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 ([°]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 (B₄) (14.901) which was on par with the application of Ca(NO₃)₂(B₂) (14.852) and KNO₃(B₃) (14.633) however lowest TSS was noticed with control (B₀) (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 of Barkule *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 phenophases significantly influenced the TSS. Maximum TSS was noticed with 705 phenophase (T₂) and lowest with 703 phenophase (T₁). 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 by Banyal and Banyal, (2020) in kiwi cv. Hayward when treated with CPPU at petal fall.

A significant difference was observed in the interaction effect between different 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 (B₄T₂) (17.300) compared to control and other treatments however the lowest TSS was noticed with control at 709 phenophase B₀T₃ (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 phenophase (T₂) 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 by Banyal 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 ($\text{mg}\cdot 100^{-1}$) 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 content in fruits. Maximum ascorbic acid content was noticed with $\text{Ca}(\text{NO}_3)_2(\text{B}_2)$ (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 $\text{Ca}(\text{NO}_3)_2$ 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 $\text{Ca}(\text{NO}_3)_2$ 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 phenophases significantly influenced the ascorbic acid content in fruits. Maximum ascorbic acid content was noticed with 709 phenophase (T_3) (46.199) which was on par with 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 between different 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 $\text{Ca}(\text{NO}_3)_2$ at 703 phenophase (B_2T_1) (50.013) which was on par with the application of $\text{Ca}(\text{NO}_3)_2$ at 705 phenophase (B_2T_2) (50.003), with the application of CaCl_2 at 705 phenophase (B_1T_2) (49.497), with the application of $\text{Ca}(\text{NO}_3)_2$ at 709 phenophase (B_2T_3) (49.503), with the application of CPPU at 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).

Shokrollahfamet *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 (Zeraatgaret *et al.* 2018) in jujube with the application of $\text{Ca}(\text{NO}_3)_2$ at three intervals ~~upto~~ up to colour change.

Table 3. Influence of chemicals and plant bioregulators application during the fruit developmental phenophase on Ascorbic acid ($\text{mg. } 100 \text{ g}^{-1}$) 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 - $\text{Ca}(\text{NO}_3)_2$ @ 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 ^c	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	

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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 sugar content in fruits. Maximum total sugar content was noticed with CPPU (B₄) (12.999) compared to control and other treatments. However, the lowest total sugar content was noticed with control (B₀) (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 (Barkuleet *et al.* 2018). The present findings are in agreement with those reported by Barkuleet *et al.* (2018) in sapota cv. Kalipatti with CPPU application

The time of application of different chemicals and plant bioregulators during fruit developmental phenophases significantly influenced the total sugar content in fruits. Maximum total sugar content was noticed with 703 phenophase (T₁) (11.655) and lowest with 709 phenophase (T₃) (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 (Barkuleet *al.* 2018). The present findings are in agreement with those reported by Barkuleet *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 between different chemicals, plant bioregulators and their time of application with respect to total sugar content in fruits. Maximum total sugars content was noticed with the application of CPPU at 703 phenophase (B₄T₁) (13.400) which was on par with the application of CPPU at 705 phenophase (B₄T₂) (12.897) however the lowest total sugars content was noticed with B₀T₂ (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. These carbohydrates 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

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 bioregulators with respect to reducing sugar content in fruits. Maximum reducing sugars content was noticed with $\text{Ca}(\text{NO}_3)_2$ (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 $\text{Ca}(\text{NO}_3)_2$ at 20 days before harvest.

The time of application of different chemicals and plant bioregulators during fruit developmental phenophase significantly influenced the reducing sugar content in fruits. Maximum reducing sugar content was 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 $\text{Ca}(\text{NO}_3)_2$ at 20 days before harvest.

A significant difference was observed in the interaction effect between different 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 $\text{Ca}(\text{NO}_3)_2$ 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 reducing sugar content was noticed with B_0T_2 (3.040). The application of $\text{Ca}(\text{NO}_3)_2$ during the fruit developmental phenophase increases reducing sugar 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 $\text{Ca}(\text{NO}_3)_2$ 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:

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 Barkuleet *al.* (2018) in sapota cv. Kalipatti with application of CPPU at 30 days before harvest.

The time of application of different chemicals and plant bioregulators significantly influenced the PLW (%) of fruits. Minimum PLW (%) of fruit was noticed with 709 phenophase (T₃). 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 Barkuleet *al.* (2018) in sapota cv. Kalipatti with 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 (%)			
	3 rd Day				6 th Day			
Days	T ₁	T ₂	T ₃	Means	T ₁	T ₂	T ₃	Means
B ₁	5.590 ^d	5.410 ^c	5.200 ^c	5.400 ^c	12.447 ^c	12.200 ^c	12.270 ^c	12.306 ^b
B ₂	5.597 ^d	5.193 ^c	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 ^c	5.672 ^b	13.100 ^b	12.500 ^c	12.003 ^c	12.534 ^b
B ₄	5.290 ^c	4.900 ^d	4.700 ^d	4.963 ^d	10.803 ^c	11.197 ^d	10.923 ^c	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	

B₁-CaCl₂, B₂-Ca(NO₃)₂, B₃- KNO₃, B₄- CPPU T₁- 703 Phenophase, T₂- 705 Phenophase, T₃- 709 Phenophase

Treatment	PLW (%)				PLW (%)			
	9 th Day				12 th Day			
Days	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 ^c	17.600 ^c	17.800 ^d	17.534 ^d
B ₂	15.267 ^c	15.737 ^b	14.043 ^c	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 ^d	14.000 ^c	12.893 ^d	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	

B₁-CaCl₂, B₂-Ca(NO₃)₂, B₃- KNO₃, B₄- CPPU T₁- 703 Phenophase, T₂- 705 Phenophase, T₃- 709 Phenophase

Comment [D7]: Explanations should be written under the tables
SE: ?
CaCl₂ ?
PLW ?
CPPU? Etc.

Applies to all tables..

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 kg cm ⁻²)				Firmness (Kg kg cm ⁻²)			
	3 rd Day				6 th Day			
Days	T ₁	T ₂	T ₃	Means	T ₁	T ₂	T ₃	Means
B₁	9.697 ^c	9.203 ^d	9.270 ^d	9.390^c	6.500 ^d	6.203 ^d	6.370 ^c	6.358^b
B₂	11.800 ^a	12.100 ^a	11.900 ^a	11.933^a	7.500 ^b	8.500 ^a	8.500 ^a	8.167^a
B₃	7.200 ^f	7.800 ^e	7.400 ^f	7.467^d	6.600 ^e	6.500 ^e	5.800 ^e	6.300^b
B₄	11.397 ^b	11.597 ^b	11.897 ^a	11.630^b	5.060 ^f	5.400 ^f	5.087 ^e	5.182^c
B₀	6.400 ^e	7.200 ^f	7.897 ^e	7.166^d	4.070 ^f	5.400 ^f	4.700 ^f	4.723^d
Means	9.299^b	9.580^a	9.673^a		5.946^e	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

B₁-CaCl₂, B₂-Ca(NO₃)₂, B₃- KNO₃, B₄- CPPU T₁- 703 Phenophase, T₂- 705 Phenophase, T₃- 709 Phenophase

Treatment	Firmness (Kg cm ⁻²)				Firmness (Kg cm ⁻²)			
	9 th Day				12 th Day			
Days	T ₁	T ₂	T ₃	Means	T ₁	T ₂	T ₃	Means
B₁	4.587 ^f	4.620 ^f	4.600 ^f	4.602^c	4.267 ^f	4.197 ^e	4.087 ^h	4.183^c
B₂	5.800 ^c	6.723 ^a	6.400 ^b	6.308^a	5.200 ^c	6.600 ^a	5.797 ^b	5.866^a
B₃	4.057 ^g	4.497 ^f	4.090 ^g	4.214^d	4.010 ^h	4.100 ^h	4.047 ^h	4.052^d
B₄	5.400 ^d	5.697 ^e	4.900 ^e	5.332^b	4.800 ^d	4.900 ^d	4.500 ^e	4.733^b
B₀	3.073 ⁱ	4.400 ^f	3.703 ^h	3.726^e	3.040 ⁱ	3.897 ^f	3.097 ⁱ	3.344^e
Means	4.583^e	5.187^a	4.739^b		4.263^b	4.739^a	4.305^b	

B₁-CaCl₂, B₂-Ca(NO₃)₂, B₃- KNO₃, B₄- CPPU T₁- 703 Phenophase, T₂- 705 Phenophase, T₃- 709 Phenophase

Among interactions CPPU and Ca treatments applied at 709 phenophase have 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. Kalipatti with 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, $\text{Ca}(\text{NO}_3)_2$ 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 Bisenet *et al.* (2012) in guava cv. Allahabad Safeda with application of $\text{Ca}(\text{NO}_3)_2$ at 20 days before harvest.

Comment [D8]: Reference is too old, should be updated

The time of application of different chemicals and plant bioregulators significantly influenced the firmness of fruits. Maximum fruit 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 Bisenet *et al.* (2012) in guava cv. Allahabad Safeda with application of $\text{Ca}(\text{NO}_3)_2$ at 20 days before harvest.

Among interactions $\text{Ca}(\text{NO}_3)_2$ applied at 705 phenophase have 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 Bisenet *et al.* (2012) in guava cv. Allahabad Safeda with application of $\text{Ca}(\text{NO}_3)_2$ 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

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 (B₄) (15.034 days) compared to control and other treatments. However, the lowest shelf life was noticed with control (B₀) (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 (Barkuleet *al.* 2018). Similar results were obtained by Barkuleet *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 (T₃) (13.549 days) which was on parwith 705 phenophase (T₂) (13.397 days) and lowest with 703 phenophase (T₁) (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 Barkuleet *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 ^c	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 ^c	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	

A significant difference was observed in the interaction effect between different 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 (B₄T₃) (15.600 days) which was on par with the application of CPPU at 705 phenophase (B₄T₂) (15.100 days) however the lowest shelf life was noticed with control at 703 phenophase (B₀T₁) (9.503). The application of CPPU during the 709 phenophase (T₃) 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. Kalipatti with application of CPPU at 30 days before harvest.

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