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Influence of pre harvest application of plant bio regulators and chemicals on post harvest quality and shelf life of Mango (*Mangifera indica* L.)

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Abstract
Present study was conducted to know the influence of pre harvest application of plant bio regulators and chemicals on post harvest quality and shelf life of mango cv. Banganpalli at fruit research station, sangareddy, Telangana, India during the 20015-16. Among plant bio regulators maximum shelf life was recorded with pre harvest application of SA (14.16 days) through maintaining the quality as well as fruit physiological parameters *viz*., total sugars (12.13%), reducing sugars (5.05%), ascorbic acid (54.62 mg/100 gm), fruit firmness (4.66 kg/cm^2) and lower PLW% (19.33%) compares to control at ripe stage. Pre harvest application of CPPU has recorded maximum shelf life (13.83 days) by maintaining the higher amounts of total sugars (12.58%) and lower PLW% (19.69%) compare to control and other group of chemicals. Among interaction between plant bio regulators and chemicals maximum shelf life was recorded with pre harvest application of SA along with boron (15.66 days) and retaining the higher amounts of ascorbic acid (60.50 mg/100 gm).

Keywords: Pre harvest application, chemicals, plant bio regulators, shelf life and quality

Introduction
Mango (*Mangifera indica* L.) is most popular and choicest of all the indigenous fruits in India. It is also a favourite fruit of the world owing to its delicious taste, nutritional value, pleasant aroma and carotene rich attractive color. Mangoes are good source of ascorbic acid, carotenoids, phenolic compounds and other dietary antioxidants that offer protection against several fatal diseases such as cancer (Talcott *et al*., 2005) [45]. India is the leader in mango production contributing 44 % of the world's production. Mango occupied an area of 2.26 million hectares with a production of 19.68 million tonnes in India. Telangana state is the fourth largest mango producing state of India and it occupies an area of 0.18 million hectares with a production of 1.68 million tonnes (NHB, 2017) [32]. The national fruit trade is expanding but mango sales are restricted by improper handling and inadequate transport facilities, because of its high perishable nature around 25-40% of post harvest losses occurs in total produce of mango (NHB, 2017) [32].

There is a lot of scope for minimizing postharvest losses by adopting different methods *viz*., storage at ambient conditions, pre-harvest sprays of bio regulators, chemicals and utilizing different packing and packaging materials etc. Among them pre-harvest sprays of bio regulators *viz*., SA, NAA, GA_3 *etc*., and chemicals *viz*., polyamines, CPPU, Calcium chloride boron *etc*., is one of the most important practices of new strategies applied in improving fruit quality attributes as well as storage life of mango. Considering the above facts, the present study was carried out to find out the influence of pre harvest application of plant bio regulators and chemicals on shelf life and bio chemical characters during storage of mango cv. Banganpalli.

Materials and methods
The Present investigation was carried out during 2015-16 at Fruit research station, Sangareddy, Telangana. Fifteen years old, well grown, uniform statured trees of mango cv. Banganpalli were selected for the experiment. Trees were spaced with 8 m and planted in square system. Paclobutrazol concentration was calculated based on the diameter of the tree, and applied @ 3 ml.m^{-1} of canopy diameter. The required paclobutrazol was dissolved in 10 litre of water, applied as soil drench 120 days before bud break (Bhagwan *et al*., 2011) [13]. 80 mg of NAA was dissolved in 50 ml of ethanol and diluted it in 1 litres of water to get 80 ppm of NAA. 100 mg of SA was dissolved in 50 ml of ethanol and diluted it in 1 litre of water to get100 ppm of SA. Ten litres of NAA 80 ppm solution was sprayed per tree 30 days before

flowering (Davenport, 2007) [14]. Ten litres of SA 100 ppm solution was sprayed per tree 30 days before flowering (Ashok kumar and Reddy 2007).

1.45 mg of spermidine was dissolved in 1 litre of water to get 0.01 mM of spermidine. 1.5 gm of boron (20%) was dissolved in 1 litre of water to get 1.5 $g.l^{-1}$ of boron. 10mg of CPPU was dissolved in 1 litres of water to get 10ppm of CPPU. Chemicals (spermidine, boron and CPPU) were sprayed at full bloom stage. The above chemicals and plant growth regulators were sprayed to observe the biochemical and physiological parameters of the fruit.

Initial weight of the fruit and final weight of the fruit were recorded and physiological loss in weight was calculated by using the formula,

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

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 percentage of total soluble solids (TSS) was determined by using 'Erma' hand refractometer and expressed as per cent TSS (^{0}Brix).Ten grams of fruit pulp was taken and ground well and then transferred to volumetric flask. The volume was made up to 100 ml in volumetric flask. The contents were filtered through Whatman No.1 filter paper and an aliquot of 10 ml was taken into conical flask to which 2-3 drops of phenolphthalein indicator was added and titrated against 0.1 N NaOH till a pink colour, as end point. The titrable acidity was estimated in terms of per cent citric acid (Ranganna, 1986) [35].

(Factor for acidity = one ml of N/NaOH = 0.0064 g of the citric acid)

$$\text{Acidity (\%)} = \frac{\text{Titre Value X Normality of NaOH X Equivalent weight of acid (g) X Volume made up to (ml) X 100}}{\text{Weight of sample taken (g) x Aliquot taken (ml)}}$$

Ascorbic acid was estimated by the procedure elicited by Ranganna (1986) [35]. Ten grams of fruit tissue was blended in 3 % meta-phosphoric 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 pink end point. The ascorbic acid was expressed as mg ascorbic acid/100 g. Reducing sugars were determined by Lane and Eynon (1965) [24] method. Ten grams of fruit pulp was taken and ground well and transferred to 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 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 brick red precipitate. The titration was carried out by keeping the Fehling's solution boiling on the heating mantle. The results were expressed as per cent reducing sugar.

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

Total sugars were determined by Lane and Eynon (1965) [24] 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 end point.

$$\text{Total sugars (\%)} = \frac{\text{Factor value x Dilution 1 x Dilution 2 x 100}}{\text{Titre value x Weigh of sample (g) x Aliquot taken (ml)}}$$

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. The statistical design adopted was factorial randomised block design with 16 treatments which were replicated thrice. The data was subjected to statistical analysis as per the procedure out lined by Panse and Sukhatme (1985) [35].

Results and discussion

Bio chemical parameters

The data (Table 1) revealed that there is significant difference among plant bio regulators with respect to TSS of fruits. Maximum TSS was noticed with paclobutrazol (B_1) (16.03) which was on par with application of SA (B_3) and control (B_0) (15.63 and 15.60), however lowest TSS was noticed with NAA application (B_2) (14.62). Both Paclobutrazol and SA has significantly increases total soluble solids in fruits at ripe condition over control. Spray of SA regulated the carbohydrates metabolism in both source and sink tissue of the plants. The hydrolysis of sucrose by invertase regulates the levels of some plant hormones like Indole 3- acetic acid, salicylic acids and jasmonates (Leclere *et al*., 2003) [25] resulting in higher levels of sugars in ripened fruits which led to higher total soluble solids (Ngullie *et al*., 2014) [31]. Paclobutrazol application involves in several enzymes activity *ie*., hydrolases, catalases, peroxidises, Nitrate reductase and IAA oxidases in mango (Vijaya laxmi and Srinivasan, 2000) [48] which might be a reason for increases in soluble solids with paclobutrazol application under present study. The similar increase in TSS was earlier obtained by Ashok Kumar and Reddy (2008) [9] in mango with SA spray, Babul Sarker and Rahim (2012) [11] in mango cv. Amrapali with Paclobutrazol application and Venkaata subbaiah *et al*., (2017) [46] in mango cv. Banganpalli with Paclobutrazol application.

Table 1: Effect of plant bio regulators and chemicals on TSS (^{0}Brix) of mango cv. Banganpalli

Treatment	TSS (^{0}Brix)				
	B_1- PBZ	B_2-NAA	B_3- SA	B_0 - Control	Mean
F_1 - Spermidine	16.50^c	16.50^c	16.60^c	17.95^c	16.88^b
F_2 - Boron	14.80^b	16.75^c	12.10^a	15.45^b	14.77^a
F_3 - CPPU	15.25^b	11.50^a	16.95^c	17.50^c	15.30^a
F_0 - Control	17.60^c	13.75^b	16.90^c	11.50^a	14.93^a
Mean	16.03^b	14.62^a	15.63^b	15.60^b	
	F -Test	S.Em±	CD at (5%)		
Factor B	*	0.314	0.921		
Factor F	*	0.314	0.921		
B×F	*	0.628	1.842		

Figures with same alphabets did not differ significantly.
** Significant at (p= 0.01 LOS), *Significant at (p= 0.05 LOS), NS- Non Significant.
Values were compared with respective C.D values.

Chemical treatments had significantly influenced the TSS. Maximum TSS was noticed with application of Spermidine (F_1) (16.88) however lowest TSS was noticed with application of boron (F_2) (14.77) which was on par with control (F_0) (14.93) and CPPU (F_3) (15.30). Polyamines shows inhibitory action on ethylene production during ripening process of fruits (Aman ullah maalik and Zora singh, 2006) [6]. At fully ripe stage polyamines except spermine did not show any appreciable inhibition of ethylene production in mango (Malik *et al*., 2006) [27]. The increase in TSS up to certain period signified the period of active synthesis of carbohydrates in fruits, while declining trend in TSS followed thereafter, indicated the degradation and fermentation of sugars signalling the onset of senescence stage (Ryall and pentzer 1974) [37], these findings were strongly confirming that delayed senescence happening in spermidine treated fruits by recording maximum TSS compare to control and other treatments. And increase in total sugars content of fruit with spermidine might be reason for higher TSS (Babul Sarkar and Rahim 2012) [11] under present investigation (Table 4). The present results are earlier agreed with findings of Malik *et al*., (2006) [27] in Kensington pride mango and Ali *et al*., (2017) [5] in mango cv. Zedba.

Table 2: Effect of plant bio regulators and chemicals on acidity (%) of mango cv. Banganpalli

Treatment	Acidity (%)				
	B_1- PBZ	B_2-NAA	B_3- SA	B_0 - Control	Mean
F_1 - Spermidine	0.045	0.037	0.041	0.035	0.039^a
F_2 - Boron	0.039	0.042	0.049	0.047	0.044^b
F_3 - CPPU	0.030	0.033	0.033	0.024	0.03^a
F_0 - Control	0.056	0.046	0.063	0.034	0.049^b
Mean	0.042	0.039	0.046	0.035	
	F -Test	S.Em±	CD at (5%)		
Factor B	*	0.004	NS		
Factor F	*	0.004	0.012		
B×F	*	0.008	NS		

Figures with same alphabets did not differ significantly.
** Significant at (p= 0.01 LOS), *Significant at (p= 0.05 LOS), NS- Non Significant.
Values were compared with respective C.D values.

Significant difference was observed in interaction effect between plant bio regulators and chemicals with respect to TSS of fruits. Maximum TSS was noticed with application of spermidine alone (B_0F_1) (17.95) which was on par with application of B_1F_0, B_0F_3, B_3F_3, B_3F_0, B_2F_2 B_3F_1 and B_1F_1 (17.60, 17.50, 16.95, 16.90, 16.75, 16.60 and 16.50 respectively) however the lowest TSS was noticed with B_0F_0 (11.50). Fruit quality parameter improving nature of both spermidine and paclobutrazol (or) SA increases TSS synergistically compare to their individual application and control. Similar synergistic increase in TSS was earlier reported by Baiea *et al*., (2015) [12] mango cv. Keitt trees treated with application of boric acid along with potassium nitrate.

The results on acidity of fruits after application of different plant bio regulators and chemicals are presented in the table 2. The data revealed that there is no significant difference among plant bio regulators with respect to acidity of fruits. Chemical treatments had significant influence with respect to acidity of fruits. Maximum acidity was noticed with application of spermidine (F_1) (0.049), which was on par with application of boron (F_2) (0.044). However lowest acidity was noticed with application of CPPU (F_3) (0.030), which was at par with control (F_0) (0.039). Spermidine and boron has increases the acidity when compares to other treatments. Increased acidity of fruit at storage might be responsible for increase in shelf life (Abhilash *et al*., 2016) [3]. The similar results were earlier reported by Malik *et al*., (2006) [27] in Keinsington pride mango with spermidine Dutta *et al*., (2018) [15] in mango cv. Himsagar with spermidine application. There is no significant difference was observed in interaction effect between plant bio regulators and chemicals with respect to acidity in fruits.

The data (Table 3) revealed that there is significant difference among plant bio regulators with respect to ascorbic acid content in fruits. Maximum ascorbic acid content was noticed with application of Paclobutrazol (B_1) (57.12), which as on par with application of SA (B_3) (54.62). However lowest Ascorbic acid content was noticed with application of NAA (B_2) (47.50), which was at par with control (B_0) (50.00). Paclobutrazol and SA could able to increase ascorbic acid significantly over control and other treatments. Ascorbic acid (vitamin c) is an important constituent of plants and has anticipated functions in photosynthesis as an enzyme cofactor and in governing cell growth. It is an important antioxidant and association with other constituents of antioxidant organization, protects plant cells from oxidative destructive process (El-sayed *et al*., 2000) [16]. Anowar Hossain *et al*., (2014) [7] indicated that vitamin C content decreased with advance in ripening process. The reduction in vitamin C content of the fruit during ripening may be due to the susceptibility of ascorbic acid to oxidative destruction particularly at high ambient storage temperature. SA treatment postponed the declining level of ascorbic acid during storage of strawberry fruits (Aghaeifard *et al*., 2016) [4]. Plant bio regulators SA and paclobutrazol used in this study might reduces spoilage or improving shelf life by delaying the depletion of ascorbic acid of mango fruits. The similar increase in ascorbic acid content of fruit was earlier agreed by Yadav *et al*., (2011) [49] in mango cv. Amrapali with application of paclobutrazol, Babul Sarker and Rahim (2012) [11] in Amrapali mango trees applied with paclobutrazol, Abd El-Razek *et al*., (2013) [1] in Hindi mango trees sprayed with SA and Faisal Ahmed *et al*., (2014) [17] in Keitt mango plants with SA spray.

Chemical treatments had significantly influence the ascorbic acid content in fruits. Maximum ascorbic acid content was noticed with application of boron (F_2) (57.62) followed by application of spermidine (F_1) (52.87). However lowest ascorbic acid content was noticed with control (F_0) (47.87), which was on par with application of CPPU (F_3) (50.87). Boron and spermidine could significantly increase the ascorbic acid content compare control. Increase in ascorbic acid content is one of the indications for delayed ripening process and quality improvement (El-sayed *et al*., 2000) [16]. The enhancement in quality of fruit could be due to the catalytic action of micronutrients particularly boric acid and zinc sulphate. Hence, the foliar application of micronutrients quickly increased the uptake of macronutrients in the tissues and organs of the mango plants, decreased the nutritional deficiencies and improved the fruit quality by improving TSS and ascorbic acid content (Moazzam *et al*., 2011) [30]. Ethylene is a plant hormone which involves or hasten ripening process in fruits (Sastry, 1970) [40], polyamines (spermidine) acts as anti ethylene substances (Apelbaum *et al*., 1981) [8]. These are the possible reasons behind increase in ascorbic acid content of fruits with chemical treatments during the study. Similar increase in ascorbic acid was earlier obtained by Aman ullah malik and Zora singh (2006) [6] in Kensington pride mango with spermine spray, Singh *et al*., (2012) [42] in mango cv. Dashehari with boron spray, Moawad *et al*., (2015) [29] in Succary mango with boric acid application and Hosseini *et al*., (2017) [21] in pear with polyamines (putrescine) application.

Table 3: Effect of plant bio regulators and chemicals on ascorbic acid (mg. 100 g^{-1}) of mango cv. Banganpalli

Treatment	Ascorbic acid (mg. 100 g^{-1})				
	B_1- PBZ	**B_2-NAA**	**B_3- SA**	**B_0 - Control**	**Mean**
F_1 - Spermidine	61.50^c	51.00^b	56.50^c	42.50^a	52.87^b
F_2 - Boron	60.00^c	57.50^c	60.50^c	52.50^b	57.62^c
F_3 - CPPU	53.00^b	46.50^b	51.50^b	52.50^b	50.87^a
F_0 - Control	54.00^b	35.00^a	50.00^b	52.50^b	47.87^a
Mean	57.12^b	47.50^a	54.62^b	50.0^a	
	F -Test	S.Em±	CD at (5%)		
Factor B	*	1.535	4.502		
Factor F	*	1.535	4.502		
B×F	*	3.070	9.005		

Figures with same alphabets did not differ significantly.
** Significant at (p= 0.01 LOS), *Significant at (p= 0.05 LOS), NS- Non Significant.
Values were compared with respective C.D values.

Significant difference was observed in interaction effect between plant bio regulators and chemicals with respect to ascorbic acid content in fruits. Maximum ascorbic acid content was noticed with application of paclobutrazol along with spermidine B_1F_1 (61.50), which was on par with application of B_3F_2, B_1F_2, B_2F_2, B_3F_1 and B_1F_3 (60.50, 60.00, 57.50, 56.50 and 53.00 respectively). However lowest ascorbic acid content was noticed with application of B_2F_0 (35.00). Paclobutrazol along with spermidine application has increase the ascorbic acid content of fruit synergistically over their individual application and control. Because of ripening delaying nature of both paclobutrazol and spermidine, combination treatment has synergistically increases the ascorbic acid content compares to their individual application. The similar synergistic increase in ascorbic acid was earlier reported by Baiea *et al*., (2015) [12] Keitt mango trees sprayed with potassium nitrate in combination with boric acid.

The results on total sugars content in fruits after application of different plant bio regulators and chemicals are presented in the table 4. The data revealed that there is significant difference among plant bio regulators with respect to total sugars content in fruits. Maximum total sugars content was noticed with application of NAA (B_2) (12.60), which was on par with application of paclobutrazol (B_1) and SA (B_3) (12.53 and 12.13). However lowest total sugars content was noticed with control (B_0) (11.23). All plant bio regulators has significantly increase total sugars over control. During the ripening process of fruits activation of hydrolytic enzymes which aid in conversion of starch, hemicelluloses and organic acids into various forms of sugars, α-amylase is one of the hydrolytic enzymes, which involves in breakdown the glucosidic linkage of starch (Glasson, 1970) [18]. SA spray increases the α-amylase activity at ripen stage over the control in mango cv. Amrapali (Singh *et al*., 2001) [43]. Other plant bio regulators used in the present study also increases total sugars at ripening, which might be activating the hydrolytic enzymes as the same way as SA. Present results were earlier confirmed with Faisal Ahmed *et al*., (2014) [17] in Keitt mango with SA spray, Babul sarker *et al*., (2016) [10] in Amrapali mango with paclobutazol and Venkat subbaiah *et al*., (2017) [46] in mango cv. Banganpalli trees applied with NAA and paclobutrazol.

Table 4: Effect of plant bio regulators and chemicals on total sugars (%) of mango cv. Banganpalli

Treatment	Total sugars (%)				
	B_1- PBZ	**B_2-NAA**	**B_3- SA**	**B_0 - Control**	**Mean**
F_1 - Spermidine	13.73^c	11.90^b	14.61^d	9.38^a	12.40^b
F_2 - Boron	10.54^a	15.85^d	10.57^a	12.25^b	12.30^b
F_3 - CPPU	13.13^c	13.06^c	11.40^b	12.75^b	12.58^b
F_0 - Control	12.74^b	9.60^a	11.94^b	10.55^a	11.20^a
Mean	12.53^b	12.60^b	12.13^b	11.23^a	
	F -Test	S.Em±	CD at (5%)		
Factor B	*	0.260	0.763		
Factor F	*	0.260	0.763		
B×F	*	0.520	1.527		

Figures with same alphabets did not differ significantly.
** Significant at (p= 0.01 LOS), *Significant at (p= 0.05 LOS), NS- Non Significant.
Values were compared with respective C.D values.

Chemical treatments had significantly influence the total sugars content in fruits. Maximum total sugars content was noticed with application of CPPU (F_3) (12.58) which was on par with application of spermidine (F_1) and boron (F_2) (12.40 and 12.30). However lowest total sugars content was noticed with control (F_0) (11.20). All the chemicals has significantly increases the total sugars over control at ripen stage. Glasson, (1970) [18] noticed that increasing trend in total sugars in fruits up to a certain peak, later on due to fermentation process of sugars declining of sugar fractions occurs during storage. Ethylene is a plant hormone which involves or hasten ripening process in fruits (Sastry, 1970) [40], polyamines (spermidine) acts as anti ethylene substances (Apelbaum *et al*., 1981) [8]. Because of delay in ripening of fruits which were treated with spermidine might be resulted in higher total sugars content compare to control fruits, which may be undergone for fruit fermentation process. The increase in total sugar content might be due to boron probably augmented the conversion of starch to sugar and it has also been opined that boron increases transportation of sugars, hydrolysis of complex polysaccharides into simple sugars, synthesis of metabolites and rapid translocation of photosynthates and minerals from other parts of the plant to developing fruits. These were the possible reasons involved in increasing of total sugars with chemical treatments. The present results are confirmed with findings of Malik *et al*., (2006) [27] in Kensington pride mango with application of spermidine, Moazzam *et al*., (2011) [30] in mango cv. Dashehari with spray of boric acid and Sankar *et al*., (2013) [39] in Alphonso mango with spray of boric acid.

Significant difference was observed in interaction effect between plant bio regulators and chemicals with respect to total sugars content in fruits. Maximum total sugars content was noticed with application of NAA along with boron (B_2F_2) (15.85), which was on par with application of SA along with spermidine (B_3F_1) (14.61). However lowest total sugars content was noticed with application of B_0F_1 (9.38). NAA along with boron application has increase the total sugars content of fruit synergistically over their individual application and control. Because of hydrolytic enzyme activation nature of plant bio regulators and starch conversion behavior of boron, in combine treatment total sugars has synergistically increased compares to their individual application. Similar increase in total sugars was earlier reported by Baiea *et al*., (2015) [12] in Keitt mango trees sprayed with potassium nitrate in combination with boric acid.

The data (Table 5) revealed that there is significant difference among plant bio regulators with respect to reducing sugars content in fruits. Maximum reducing sugars content was noticed with application of SA (B_3) (5.05), which were on par with application of paclobutrazol (B_1) and NAA (B_2) (4.97 and 4.95). However lowest reducing sugars content was noticed with control (B_0) (4.29). All plant bio regulators has significantly increase reducing sugars over control. During the ripening process of fruits activation of hydrolytic enzymes which aid in conversion of starch, hemicelluloses and organic acids into various forms of sugars, α-amylase is one of the hydrolytic enzymes, which involves in breakdown the glucosidic linkage of starch (Glasson, 1970) [18]. SA spray increases the α-amylase activity at ripen stage over the control in mango cv. Amrapali (Singh *et al*., 2001) [43]. Other plant bio regulators used in the present study also increases reducing sugars at ripening, which might be activating the hydrolytic enzymes as the same way as SA. Present results were earlier confirmed with Faisal Ahmed *et al*., (2014) [17] in Keitt mango with SA spray, Babul sarker *et al*., (2016) [10] in Amrapali mango with paclobutazol and Venkat subbaiah *et al*., (2017) [46] in mango cv. Banganpalli trees applied with NAA and Paclobutrazol.

Chemical treatments had significantly influence the reducing sugars content in fruits. Maximum reducing sugars content was noticed with application of spermidine (F_1) (5.59) followed by application of boron (F_2) (5.14), which was on par with control (F_0) (4.78) however lowest reducing sugars content was noticed with application of CPPU (F_3) (3.75). Ethylene is a plant hormone which involves or hasten ripening process in fruits (Sastry, 1970) [40], polyamines (spermidine) acts as anti ethylene substances (Apelbaum *et al*., 1981) [8]. Because of delay in ripening of fruits which were treated with spermidine might be resulted in higher total sugars content compare to control fruits, which may be undergone for fruit fermentation or senescence process. This might be a reason for high reducing sugars in fruits which were treated with spermidine. The present results were confirmed with findings of Malik *et al*., (2006) [27] in Kensington pride mango with application of spermidine

Table 5: Effect of plant bio regulators and chemicals on reducing sugars (%) of mango cv. Banganpalli

Treatment	Reducing sugars (%)				
	B_1- PBZ	B_2-NAA	B_3- SA	B_0 - Control	Mean
F_1 - Spermidine	6.08^c	4.47^b	6.66^c	5.17^b	5.59^c
F_2 - Boron	4.29^b	6.43^c	5.00^b	4.86^b	5.14^b
F_3 - CPPU	3.97^b	4.65^b	2.47^a	3.92^b	3.75^a
F_0 - Control	5.57^b	4.25^b	6.10^c	3.23^a	4.78^b
Mean	4.97^b	4.95^b	5.05^b	4.29^a	

	F -Test	S.Em±	CD at (5%)
Factor B	*	0.166	0.489
Factor F	*	0.166	0.489
B×F	*	0.333	0.978

Figures with same alphabets did not differ significantly.
** Significant at (p= 0.01 LOS), *Significant at (p= 0.05 LOS), NS- Non Significant.
Values were compared with respective C.D values.

Significant difference was observed in interaction effect between plant bio regulators and chemicals with respect to reducing sugars content in fruits. Maximum reducing sugars content was noticed with application of SA along with spermidine (B_3F_1) (6.66), which was on par with B_2F_2, B_3F_0 and B_1F_1 (6.43, 6.10 and 6.08 respectively). However the lowest fruit reducing sugars was noticed with B_3F_3 (2.47). Because of hydrolytic enzyme activation nature of plant bio regulators and slow senescence or fermentation process of spermidine behavior, in combine treatments the reducing sugars has synergistically increases compares to their individual application. Similar increase in reducing sugars was earlier reported by Baiea *et al*., (2015) [12] in Keitt mango trees sprayed with potassium nitrate in combination with boric acid.

Physiological parameters

The data depicted in fig. 1 revealing that there is a gradual increase in PLW (%) with storage period. All plant bio regulators could significantly minimize the PLW (%) over control. Physiological weight loss is a continuous phenomenon during storage caused due to moisture loss. Moisture loss through respiration and transpiration during storage affects the net weight and eventually the fruit becomes unsalable as a result of shrinking (Salunkhe, 1984) [38]. Ethylene is responsible for hastening ripening process which involves increased respiration and transpiration changes with progress of storage period might be responsible for PLW (%) of fruits (Khader *et al*., 1988) [23]. Ethylene evolution rate increased rapidly in the control (untreated) fruits, which achieved its peak on 3rd day of storage and then it declined slowly towards the end of storage period. The ethylene peak was delayed to 9th day in those treated with SA (150 and 200 ppm) (Vijay rakesh reddy *et al*., 2016) [47]. Such suppression in ethylene production in SA-treated mango fruit might be associated with the decreased in ACC synthase (Srivastava and Dwivedi, 2000) [44] and /or ACC oxidase activity as reported in banana (Srivastava and Dwivedi, 2000) [44] and apple (Shirzadeh and Kazemi, 2012) [41]. This might be reason involved in low PLW (%) with SA (19.33 %) treatment. The other plant bio regulators used under the study might be act as same like SA in reducing PLW (%) of fruits. Similar results were earlier reported by Luo *et al*., (2011) [26] in plum fruits with spray of SA.

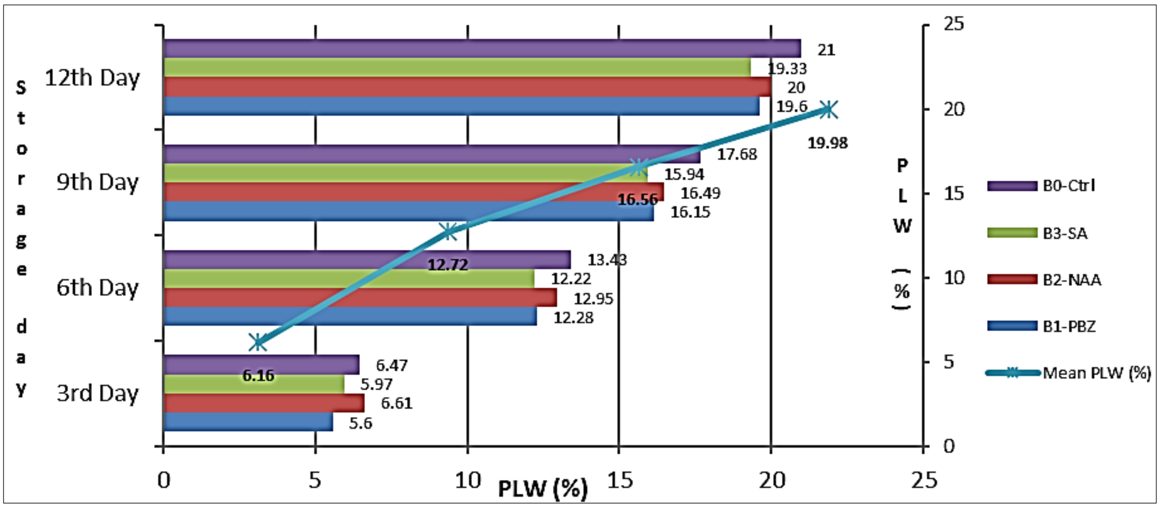

Fig 1: Effect of plant bio regulators on PLW (%) of mango cv. Banganpalli

Among chemicals (fig. 2) spermidine (18.92 %) and CPPU (19.69%) has significantly minimize the PLW (%) over control and other treatments. Polyamines (spermidine) treatments led to a reduced physiological weight loss during storage, which may due to the reduced rate of respiration compared to control (Malik *et al*., 2006) [27]. As earlier discussed Ethylene is responsible for hastening ripening process which involves increased respiration and transpiration changes with progress of storage period might be responsible for PLW (%) of fruits (Khader *et al*., 1988) [23]. Endogenous ethylene production rate was reduced when Japanese pear fruits sprayed with CPPU and resulted in delayed ripening. These are the possible reasons behind minimization in physiological loss of weight with chemicals used in present study. Similar finding was earlier reported by Malik *et al*., (2006) [27] in Kensington pride mango fruit treated with spermidine and Pujari *et al*., (2016) [34] in mango cv. Amrapali with application of CPPU.

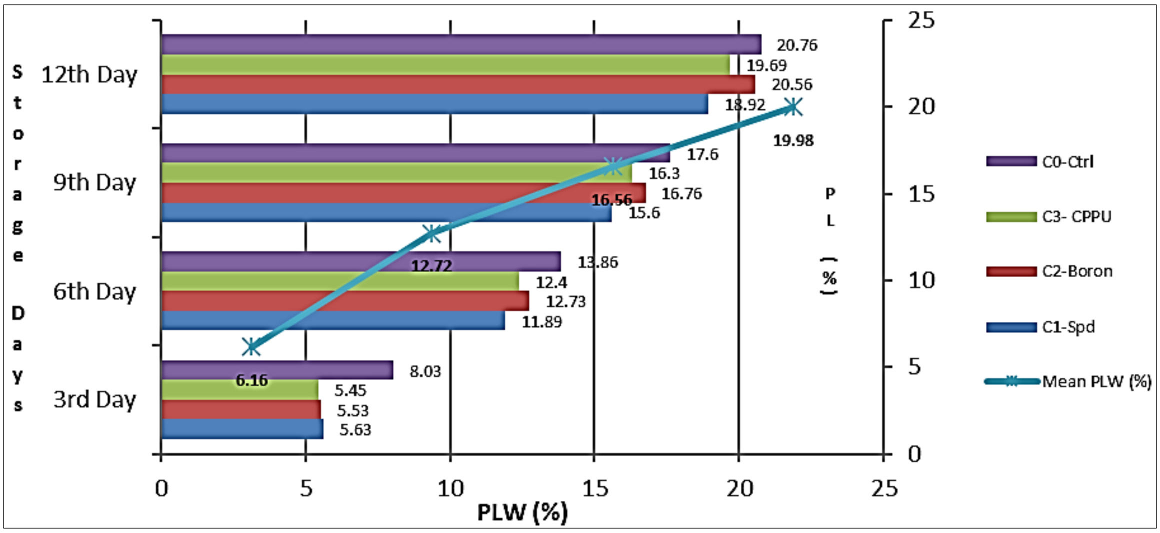

Fig 2: Effect of chemicals on PLW (%) of mango cv. Banganpalli

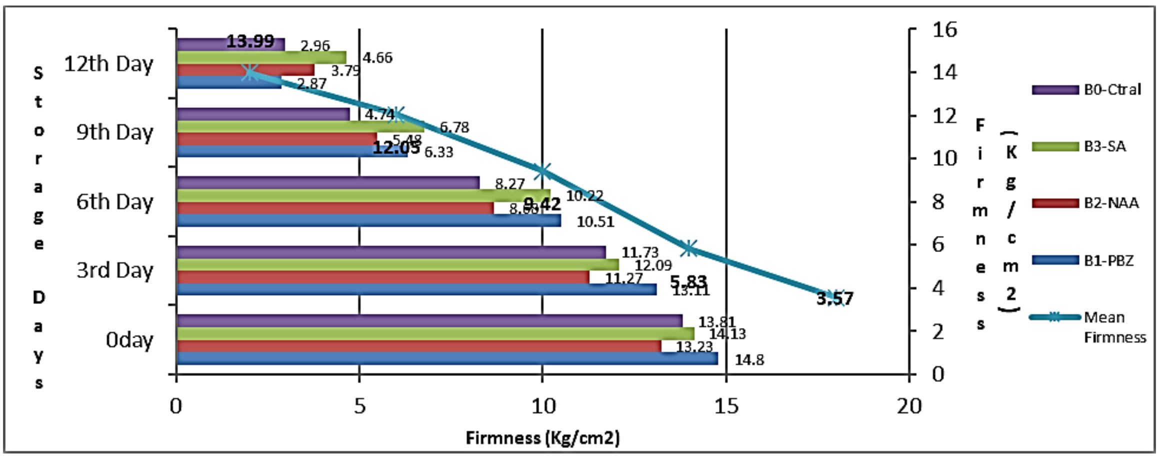

Fig 3: Effect of plant bio regulators on Firmness (Kg/cm^2) of mango cv. Banganpalli

The data presenting in the fig. 3 indicating that there is gradual decrease in firmness with storage period. Fruit firmness 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, hemicelluloses in the fruit (Rao *et al.*, 1971) [36]. Further the firmness indicates the progression of ripening in climacteric fruits. Among plant bio regulators SA treatment has effectively increases the firmness (4.66) over control and other treatments at end of storage period. As earlier discussed SA has inhibits the ethylene production during storage which is responsible for ripening and fruit softening (Vijay rakesh reddy *et al.*, 2016) [47]. Present results are earlier agreed with the findings of Faisal Ahmed *et al.*, (2014) [17] in mango cv. Keitt and Hong *et al.*, (2014) [20] in mango fruits.

Among chemicals (Fig. 4) spermidine has significantly increases the firmness (4.12) over control and other treatments at end of storage period. Retardation of fruit softening with the application of polyamines (spermidine) may be due to the inhibition of polygalacturonase activities, presumably through binding to pectin substances (Karmer *et al.*, 1989) [22]. Similar findings was earlier reported by Malik *et al.*, (2006) [27] in mango cv. Kensington pride with spermidine application and Hosseini *et al.*, (2017) [21] in Spadona pear with putrescine application.

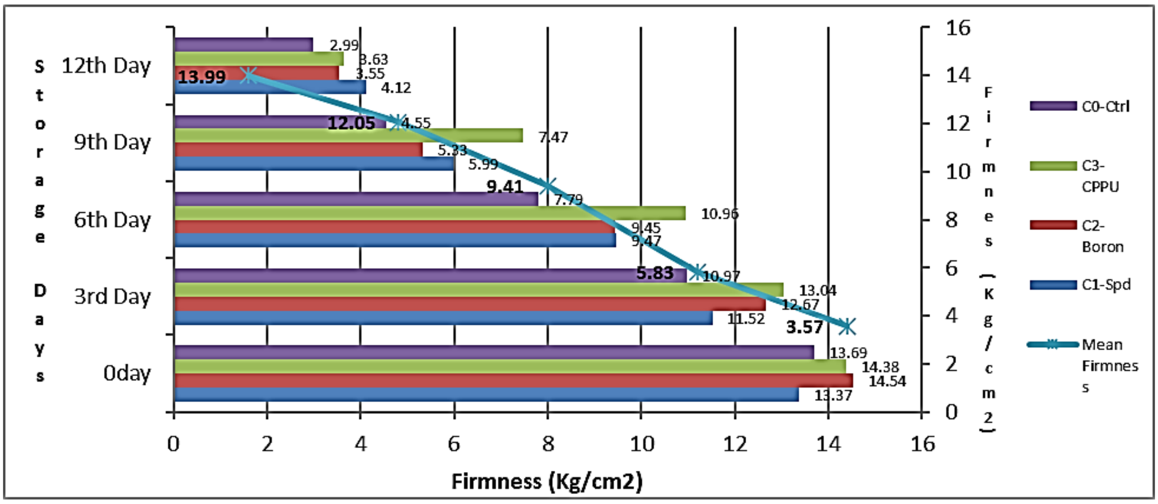

Fig 4: Effect of chemicals on Firmness (Kg/cm^2) of mango cv. Banganpalli

The data (Table 6) revealed that there is significant difference among plant bio regulators with respect to shelf life of fruits. Maximum shelf life was noticed with application of SA (B_3) (14.16), which was on par with application of Paclobutrazol (B_1) (13.58). However lowest shelf life was noticed with control (B_0) (12.83), which was at par with application of NAA (B_2) (13.24). SA and Paclobutrazol has significantly increase the shelf life compare to control and other treatments. As earlier discussed SA has inhibits the ethylene production which is responsible for ripening and senescence (Vijay rakesh reddy *et al.*, 2016) [47] and paclobutrazol reduces PLW (%) (Fig. 1). These might be reasons for extending of fruit shelf life with plant bio regulators used under this study. Similar increase in shelf life was earlier reported by Babul Sarker and Rahim (2012) [11] in Amrapali mango with application of paclobutrazol and Hamideh Mohammadi *et al.*, (2015) [19] in Elberta peach with SA application.

Chemical treatments had significantly influence the Shelf life of fruits. Maximum shelf life was noticed with application of CPPU (F_3) (13.66), which was on par with application of boron (F_2) and spermidine (F_1) (13.83 and 13.58). However, minimum shelf life was noticed with control (F_0) (12.74). As earlier discussed spermidine acts as anti ethylene substances (Apelbaum *et al.*, 1981) [8], CPPU and boron could effectively increases fruit firmness and reduces PLW (%) during storage period (Fig. 2 and Fig. 4). These might be the possible reasons behind increase in shelf life of fruit with application of chemical treatments used under this study. Similar line of findings were earlier reported by Malik *et al.*, (2006) [27] in Kensington pride mango with spermidine application and Manjot Kaur and Amarjeet Kaur (2019) [28] in peach cv. Flordaprince with application of polyamines.

Table 6: Effect of plant bio regulators and chemicals on Shelf life (days) of mango cv. Banganpalli

Treatment	Shelf life (days)				
	B_1- PBZ	B_2-NAA	B_3- SA	B_0 - Control	Mean
F_1 - Spermidine	12.33^a	14.33^b	12.33^a	15.33^c	13.58^b
F_2 - Boron	14.66^b	12.33^a	15.66^c	12.00^a	13.66^b
F_3 - CPPU	15.00^b	13.66^b	14.33^b	12.33^a	13.83^b
F_0 - Control	12.33^a	12.66^a	14.33^b	11.66^a	12.74^a
Mean	13.58^b	13.24^a	14.16^b	12.83^a	
	F -Test		S.Em±		CD at (5%)
Factor B	*		0.228		0.670
Factor F	*		0.228		0.670
B×F	*		0.456		1.340

Figures with same alphabets did not differ significantly.
** Significant at (p= 0.01 LOS), *Significant at (p= 0.05 LOS), NS- Non Significant.
Values were compared with respective C.D values.

Significant difference was observed in interaction effect between plant bio regulators and chemicals with respect to shelf life in fruits. Maximum shelf life was noticed with application of SA and boron (B_3F_2) (15.66), which was on par with application of B_0F_1 (15.33). However the lowest shelf life was noticed with B_0F_0 (11.66). SA and boron combined application has synergistically increases shelf life over control and their individual application. Retarding or slowdown ripening nature of SA and boron, in combined application shelf life of fruits was increased synergistically compares to control and their individual application. Similar synergistic increase in shelf life was earlier reported by Abdel Gayed *et al.*, (2017) [2] in peach with application of calcium chloride along with chitosan.

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