The Pharma Innovation Journal 2022; 11(11): 1844-1857

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(11): 1844-1857
© 2022 TPI
www.thepharmajournal.com
Received: 21-09-2022
Accepted: 24-10-2022

# Effect of pre-harvest spray of bio-regulators and bagging on yield and post-harvest quality of mango (*Mangifera indica* L.) cv. Banganpalli

**J RaviKanth, A Bhagwan, A Kiran Kumar, S Narender Reddy, M Sreedhar and Purnima Mishra**

**J RaviKanth**
Department of Horticulture, College of Horticulture, Rajendranagar, Hyderabad, Sri Konda Laxman Telangana State Horticultural University, Mulugu, Siddipet, Telangana, India

**A Bhagwan**
Department of Horticulture, College of Horticulture, Rajendranagar, Hyderabad, Sri Konda Laxman Telangana State Horticultural University, Mulugu, Siddipet, Telangana, India

**A Kiran Kumar**
Department of Horticulture, College of Horticulture, Rajendranagar, Hyderabad, Sri Konda Laxman Telangana State Horticultural University, Mulugu, Siddipet, Telangana, India

**S Narender Reddy**
Professor, Jayashankar Telangana State Agriculture University, Hyderabad, Telangana State, India

**M Sreedhar**
Professor, Jayashankar Telangana State Agriculture University, Hyderabad, Telangana State, India

**Purnima Mishra**
Department of Horticulture, College of Horticulture, Rajendranagar, Hyderabad, Sri Konda Laxman Telangana State Horticultural University, Mulugu, Siddipet, Telangana, India

**Corresponding Author:**
**J RaviKanth**
Department of Horticulture, College of Horticulture, Rajendranagar, Hyderabad, Sri Konda Laxman Telangana State Horticultural University, Mulugu, Siddipet, Telangana, India

**Abstract**
A field experiment was carried out at Fruit Research Station, Sangareddy, Telangana State during the year 2015- 2017 to study the effect of pre harvest spray of bio-regulators ($S_1$ - Ca $(NO_3)_2$ @ 1%, $S_2$ - Putrescine @ 0.1mM, $S_3$- CPPU (1-(2- Chloro-4-Pyridyl)-3-Phenyl Urea) @ 10 ppm, $S_4$ - Ca $(NO_3)_2$ @ 1%+ Putrescine @ 0.1mM+ CPPU @ 10 ppm, $S_5$ - Control) and bagging ($B_1$ - Two layers of brown paper, $B_2$ - No bagging) on export quality characters of mango cv. Banganpalli. The experiment results revealed that the pre-harvest spray of Ca $(NO_3)_2$ @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm and bagging with two layers of brown paper ($S_4B_1$) resulted in maximum fruit TSS (18.47 °Brix) and shelf life (12.97 days) with better post-harvest quality attaining highest scores for all organoleptic characters evaluated *viz.*, colour score (8.96), taste score (8.60), texture score (8.40), flavour score (8.7) and overall acceptance score (8.66).

**Keywords:** Bio-regulators, (Ca $(NO_3)_2$, Putrescine, CPPU (1-(2- Chloro-4-Pyridyl)-3-Phenyl Urea)) and Bagging

## Introduction

Mango (*Mangifera indica* L.) belongs to the family Anacardiaceae considered as one of the most important fruits of the tropical and subtropical countries. India occupies the top position among mango growing countries of the world and produces 40.1% of the total world production. It is the premier and choicest fruit of India and undoubtedly one of the best fruits of the world. It is known as 'King of Fruits' due to its captivating flavour, irresistible taste and sweetness. Very aptly, Indians designated this fruit as the 'National Fruit' of the country. Mango is a highly nutritive fruit. It plays an important role in balancing the human diet by providing about 64-86 calories per 100 grams of ripe fruits (Rathore *et al.* 2007) [91]. It is a good source of vital protective nutrients like vitamins A, B, and C, niacin and is also rich in minerals including calcium, potassium and iron.

To improve the production and productivity in mango, there is a need to improve the physical appearance and exportable quality of the fruit to full fill the global market demand. Attractive fruits fetch a premium rate in the market. There are various approaches to improve the external appearance of the fruit. Bagging of fruit is one of the novel ways among these various means. Bagging is covering individual fruit with specially designed paper or cloth bags. Bagging protects fruits from pests, fungal infections, diseases, mechanical damage, reduces spraying of insecticides and provides an estimate of harvestable fruits per tree. Bagging of fruits is done to prevent damage occurring due to bruises, wounds, scars, diseases and pest attack and also to produce cleaner fruit skin with attractive colour. Moreover, reports are indicating that pre-harvest spray of bio regulators will improve the fruit physical and quality parameters. CPPU @ 10 ppm is effective for the improvement of fruit size through stimulating cell division in mango (Sasaki and Utsunomiya 2012) [98]. Exogenous application of polyamines has been demonstrated to influence yield, shelf life and quality of various fruit crops such as apple (Kramer *et al.*, 1989) [60], strawberry, plum (Ren *et al.*, 1995) [92], peaches (Romero *et al.*, 2000) [93] and mango (Purwoko *et al.*, 1998) [88]. The pre-harvest application of calcium nitrate is known to influence the quality and shelf-life of fruits during storage (Gill *et al.*, 2005) [32]. However, the studies made in combination of bagging and pre harvest spray of bio regulators was meagre in mango. In mango, heavy fruit drop and low shelf life are important factors contributing to low yield and fruit quality.

Pre-harvest application of bio regulators and bagging will improve the fruit yield and its quality in mango (Notodimedjo, S., 2000; Khattab *et al.*, 2005 and Jakhar and Pathak, 2014) [82, 56, 47]. The aim of the present study was to determine the effect of pre-harvest bio regulators application and fruits bagging on post-harvest quality and shelf life of mango fruits cv. Banganpalli.

## Material and Methods

### Plant Material and Treatment

The present investigation was carried out during two succeeding seasons *i.e.,* 2015-16 and 2016-17 at Fruit Research Station, Sangareddy, SKLTSHU, Telangana State is situated at an altitude of 560.3 meters above mean sea level on 18º.03 North latitude and 78º.18 East longitude, with an annual average temperature of 26.0 °C and rainfall of 910 mm. The climate of Sangareddy is tropical, semi-arid and dry. Eight years old bearing trees of mango cv. Banganpalli, having uniform vigor and health were selected mango orchard. Trees were spaced 8×8 m and received uniform pruning and cultural operations. Sixty selected trees were subjected to ten pre-harvest treatments *viz*. $B_1$ $S_1$ - Two layers of brown paper + Ca $(NO_3)_2$ @ 1%, $B_1$ $S_2$- Two layers of brown paper + Putrescine @ 0.1mM, $B_1$ $S_3$- Two layers of brown paper + CPPU @ 10 ppm (1-(2- Chloro-4-Pyridyl)-3-Phenyl Urea), $B_1$ $S_4$- Two layers of brown paper + Ca $(NO_3)_2$ @ 1%+ Putrescine @ 0.1mM + CPPU @ 10 ppm, $B_1$ $S_5$- Two layers of brown paper + Control, $B_2$ $S_1$ - No bagging + Ca $(NO_3)_2$ @ 1%, $B_2$ $S_2$ - No bagging +Putrescine @ 0.1mM, $B_2$ $S_3$ - No bagging + CPPU @ 10 ppm (1-(2- Chloro-4-Pyridyl)-3-Phenyl Urea), $B_2$ $S_4$- No bagging + Ca $(NO_3)_2$ @ 1%+ Putrescine @0.1mM + CPPU @ 10 ppm, $B_2$ $S_5$- No bagging + Control with three replications. One tree was taken as a unit for a replication of treatment.

### Treatments Methodology

Fruits were bagged at 30 days before harvesting of fruits using two brown paper bags per fruit. Twenty uniform sized fruits were marked at all directions of the canopy of the trees. Individual fruit was covered with brown paper bags and tied with thread on the stalk of fruits. Before bagging all selected tress were sprayed with above mentioned bio regulators.

### Fruit Harvest and Storage

Fruits of all trees were separately harvested at optimum maturity stage by hand with 1.0 cm stalk to escape any damage of fruit. Harvesting was done in the morning hours during both years. The field heat of harvested fruits was removed by dipping in fresh water and then carefully sorted and graded as fresh and uniform sized fruits. These fruits were transported from orchard to the laboratory without any type of physical damage including bruising. In the laboratory, fruits were washed in running tap water and cleaned with muslin cloth. Fruits were packed in corrugated fiber board boxes with the use of newspaper as liner. All boxes were tagged as per treatments and stored under ventilated room (at ambient temperature) for 15 days.

### Fruit physical parameters analysis

Days taken for fruit maturity (From fruit set to harvest) was recorded by counting calendar days from fruit set to fruit, number of fruits tree$^{-1}$ (at the time of harvest) calculated by adding different interval harvested fruits, yield (kg tree$^{-1}$) recorded by using a manual weighing balance and the yield per plant was calculated by adding the weight of each harvest (Vijay Krishna, 2019) [117]. Fruit length (cm) and breadth (cm) were measured with digital vernier callipers, weight (g) measured with digital electronic balance.

### Canopy volume (m$^3$)

The canopy volume (from the root base of a tree to maximum spreading) was measured using tape (fastened on a bamboo stick) and calculated by the formula suggested by Samaddar and Chakrabarti (1988).

Canopy volume (m3) = 4/3 π(r2h)

Where r = diameter/2, h= height of the plant. The canopy diameter was measured in both the direction (NS and EW) of the canopy. Plant height (m) was measured from graft union to the top of the tree by measuring tape (fixed on a bamboo stick).

### Fruit Quality Analysis

Fruit specific gravity determined by dividing the weight of the fruit in the air by the volume of the fruits obtained by the water displacement method (Gustafson, 1926) [36]. Total soluble solids ($^0$Brix) measured by using the 'Erma' hand refractometer. The total titratable acidity was calculated on the basis of one ml N/10 NaOH equivalent to 0.0064 g of anhydrous citric acid or per cent citric acid in juice. Sugar to acid ratio was calculated by dividing TSS (%) with titratable acidity (%). The total sugars were estimated by titrating the boiling mixture of 5 ml, each of Fehling A and Fehling B solution against the hydrolyzed aliquot by using methylene blue as an indicator. Non-reducing sugars were calculated by substracting reducing sugars from the total sugars and multiplying the difference by standard factor i.e., 0.95 and ascorbic acid was determined by AOAC (1980) method. The shelf life was determined by recording the number of days the fruits remained in good condition without spoilage. The organoleptic evaluation of ripe mango fruits was done on a 10-point Hedonic scale by a panel of five judges and scores were allotted accordingly for the fruits of each treatment for various quality attributes such as colour, aroma, texture and acceptability. The data obtained from the investigation were statistically analyzed according to the procedure out lined by Panse and Sukhatme (1985) [84].

## Results and Discussion

1. **Number of days taken from fruit set to maturity (days)**

Regarding the effect of the pre-harvest spray of different bio-regulators (S), application of Ca $(NO_3)$ @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm ($S_4$) has recorded (Table 1) the minimum number of days from fruit set to maturity (126.08 days) whereas the maximum number of days from fruit set to maturity (149.01 days) was recorded in control ($S_5$). Cytokinins are a class of plant hormones that promote cell division, or cytokinesis. They are involved primarily in cell growth and differentiation. Cell division at the early stage of fruit development has a major role in final fruit growth and size (Flaishman *et al.*, 2001; Biswal and Rout, 2020) [28, 15]. At the early stage of fruit growth, CPPU stimulates effective cell division (Zhang *et al.*, 2007; Biswal and Rout, 2020) [15, 126]. The positive effect of putrescine application on fruit development might be attributed to increased nutrient uptake thereby improved fruit set and enhanced metabolic processes such as carbohydrate transport (El-Migeed *et al.*, 2013) [24] resulting in improved fruit size and early development of fruits. The application of CPPU might have altered sink-source relations with more carbohydrate transport to developing fruits which led to improved fruit size (length) (Table1) and fruit weight (Table 1) thus resulting in early development and maturity of fruits compared to control in the present study. Similar improved fruit development was reported earlier by Notodimedjo *et al.*, (2000) [82] in Arumanis mango, Kulkarni *et al.*, (2017) [61] in Kesar mango, Gattas *et al.*, (2018) [30] in Keitt mango trees sprayed with CPPU and Shaban *et al.* (2017) [100] on Ewais mango, Buronkar (2005) [19] in Alphonso mango trees, Naser *et al.* (2016) [79] in date palm and Fakir and Abed AL-Hussain (2009) on tomato sprayed with putrescine. Further, the calcium might be responsible for faster cell division and cell enlargement thereby increases in fruit volume (Sankar *et al.*, 2013) [97]. Nitrates are the most readily available form of N for root absorption (Khan *et al.*, 2015) [55]. A high N concentration stimulates the activities of the enzymes associated with ethylene synthesis (Tian *et al.*, 2009; Khan *et al.*, 2015) [112, 55]. Ethylene might be an important second messenger in promoting flowering, fruit maturity and ripening (Burg and Burg, 1966) [18]. These were the possible reasons for early fruit maturity with $M_4$ treatment under the present investigation. Similar minimization in the number of days taken for harvest from fruit set was earlier found by Raj Kumar *et al.*, (2006) [89] in mango with Ca $(NO_3)_2$, Vijay Krishna *et al.*, (2012) [116] in mango cv. Banganpalli with Ca $(NO_3)_2$ spray and Maurya *et al.*, (2016) [72] in aonla cv. NA-6 with a spray of Ca $(NO_3)_2$ and potassium sulphate.

Regarding the effect of bagging treatments (B), bagging with two layers of brown paper ($B_1$) recorded the minimum number of days from fruit set to maturity (129.61 days) whereas control ($B_2$) recorded the maximum number of days from fruit set to maturity (141.96 days). The abiotic factors *viz.* temperature and humidity play a critical role in fruit growth and development (Kireeti *et al.*, 2018) [58]. Islam *et al.*, (2017) [45] reported that the microenvironment created by bagging material might have a congenial effect on the fruit growth of mango. Bagging improving fruit size was considered as a result of temperature increase (Wang *et al.*, 2007) [119] or a result of humidity increase (Tombesi *et al.*, 1993; Thorp *et al.*, 2007; Wang *et al.*, 2007) [113, 111, 119]. So, the warm temperature and increased humidity inside the brown paper bag might have contributed to the early growth and development of fruits resulting in the fewer number of days recorded from fruit set to maturity. These results are in agreement with the findings of Debnath and Mitra (2008) [23] who reported that an increase in the temperature of microclimate inside the cellophane paper bags (different colours) caused earlier accumulation of the required heat units than un-bagged fruits, resulting in the advancement of fruit maturity in litchi.

However, the interaction effect of the pre-harvest spray of different bio-regulators and bagging (SxB) was found non-significant.

### 2. Number of fruits per tree at the time of harvest

Effect of different bio-regulators (S) and bagging (B) and their interaction (SxB) in mango cv. Banganpalli found non-significant (Table 1).

### 3. Fruit length (cm) and fruit breadth (cm)

Application of Ca ($NO_3$) @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm ($S_4$) recorded maximum fruit length (8.83 cm) which was on par with that of application of CPPU @ 10 ppm ($S_3$) (8.61 cm) whereas minimum fruit length (8.47 cm) was recorded with the application of Ca ($NO_3$) @ 1% ($S_1$) which was on par with fruit lengths recorded (8.47 cm and 8.60cm) with the application of Ca ($NO_3$) @ 1% ($S_1$) and Putrescine @ 0.1mM ($S_2$) respectively (Table 1). This might be due to the exogenous application of CPPU acts early on cell division in the fruit and also on subsequent growth. Thus, the fruit becomes bigger due to efficient cells, the building blocks of fruit mass and also because the cells have been able to attract so much water, minerals and carbohydrates that enable the fruit to expand to large size (Kano, 2003; Kulkarni *et al.*, 2017) [51, 61]. Calcium is an important mineral in the formation of cell membrane and development hence increases in the fruit physical attributes (Bitange *et al.*, 2019) [16]. Calcium improves the efficiency of photosynthesis and is associated with hormone metabolism, which promotes the synthesis of auxins, essential for fruit growth (Kazemi, 2014; Mosa *et al.*, 2015) [53, 75] and thus it might have contributed to the increased fruit length. Further, Polyamines are associated with cell division (Shaban *et al.*, 2017) [100].

The exogenous application of putrescine might have improved cell size or cell number resulting in improvement of fruit growth and uptake of nutrients that accelerate metabolic processes (El-Migeed *et al.*, 2013) [24] thus increasing the fruit length. A similar increase in fruit length and size was reported earlier by Kulkarni *et al.*, (2017) [61] in mango cv. Kesar, Greene (2001) [35] in McIntosh apple, Said (2002) [95] on Anna apple, Stern *et al.* (2002) [110] on pear and Nampila *et al.* (2010) [78] on the grape with the application of CPPU, Bitange *et al.* (2019) [16] in mango, Kumar *et al.* (2003) in mango cv. Baneshan, Karemera and Habimana (2013) in mango cv. Totapuri, Kumari *et al.* (2018) [65] in mango cv. Langra and Purohit *et al.* (2019) [87] in guava cv. L-49 with the application of calcium nitrate and El-Migeed *et al.*, (2013) [24] in Amhat date palm, Ayad *et al.* (2011) [8] on olive and Ali *et al.* (2010) on apricot with the application of putrescine. However, no significant difference was found in fruit breadth among the treatments with a pre-harvest spray of different bio-regulators (S).

Regarding the effect of bagging treatments (B) on fruit length and breadth, bagging with two layers of brown paper ($B_1$) recorded maximum fruit length (8.75 cm) and fruit breadth (7.71 cm) whereas control (no bagging) ($B_2$) was recorded minimum fruit length (8.51 cm) and fruit breadth (7.61 cm). Bagging affects the size and the weight of pomegranate (Hussein *et al.*, 1994; Padmavathamma and Hulamani, 1996) [44, 83], bitter gourd (Kuo *et al.*, 1999) [66], apple (Arakawa *et al.*, 1994) [6] and banana (Johns and Scott, 1989; Hasan *et al.*, 2001) [49, 39] fruits. Bagging improving fruit size was considered as a result of temperature increase (Wang *et al.*, 2007) [119] or a result of humidity increase (Tombesi *et al.*, 1993; Thorp *et al.*, 2007; Wang *et al.*, 2007) [111, 113, 119]. This increased fruit size can be attributed to the microenvironment created by bagging material which might have a congenial effect on fruit growth (Islam *et al.*, 2017) [45]. These findings are in accordance with some previous reports that the effects of pre-harvest bagging increased fruit growth, size, and weight by Islam *et al*, (2017) [45] in mango cv. Mishribhog, Islam *et al.*, (2019) [46] in mango cv. Langra with brown paper bags. Yang *et al.*, (2009) in longan fruit; Harhash and Al-Obeed, (2010) [38] in date palm and Zhou *et al.*, (2012) [127] in mango. Kireeti *et al.*, (2018) [58] also reported increased fruit length of mango cv. Kesar significantly by bagging with newspaper bag and brown paper bag over control. Further, Xu *et al.* (2008) reported an increase in fruit width due to bagging in the carambola.

Further, no significant difference was found among the treatments regarding fruit length and fruit breadth with the interaction effect of the pre-harvest spray of different bio-regulators and bagging (SxB) in mango cv. Banganpalli.

## 4. Fruit weight (g)

Application of Ca $(NO_3)$ @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm $(S_4)$ resulted in maximum fruit weight (294.43 g) whereas minimum fruit weight (256.51 g) was recorded in control with no chemical spray $(S_5)$ (Table 1). This increase in fruit weight with application of Ca $(NO_3)$ @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm $(S_4)$ could be attributed to increase in fruit size (length) with this treatment in the present study. Cell division and enlargement of the cell is a complicated process involving the synthesis of many organic compounds such as proteins, cellulose and nucleic acids in mango (Kumar, 2006). Calcium might be responsible for cell division and enlargement thereby increase in fruit length and volume which were directly proportional to fruit weight (Sankar *et al.*, 2013) [97]. Calcium increase weight might be due to faster mobilization of metabolites in the fruits and involvement in cell division and cell expansion as well as the increase in the volume of intercellular space in mesocarpic cells (Purohit *et al.*, 2019) [87]. The above finding is in accordance with the results of Parkhe *et al.* (2015) [85] in guava. The findings are confirmed with findings of Purohit *et al.*, (2019) [87] in guava cv. L-49, Sankar *et al.*, (2013) [97] in Alphonso mango and Jyothi *et al.*, (2018) [50] in mango cv. Langra. CPPU is a synthetic cytokinin that can stimulate cell division and cell elongation in pear (Flaishman *et al.*, 2001) [28]. Any increase in length, width and thickness of fruit brought a corresponding increase in weight of fruit (Kulkarni *et al.*, 2017) [61], the possible explanation for the increase in fruit size and weight was also due to faster movement of simple sugars and involvement in cell expansion (Brahmachari *et al.*, 1996) [17]. CPPU increases cell size and is also responsible for the production and transport of plant sugars that increase the weight of fruit (Singh *et al.*, 1994). These reasons might be responsible for the increase in fruit weight with the CPPU application. A similar increase in fruit weight with CPPU was earlier reported by Kumar *et al.*, (2013) in apple cv. Red delicious, Kulkarni *et al.*, (2017) [61] in Kesar mango and Gattass *et al.*, (2018) [30] in Keitt mango trees. Application of putrescine improves cell size or cell number resulting in improvement of fruit growth and uptake of nutrients that accelerate metabolic processes. This improvement in nutrient status increases the rate of sugar transport to actively growing regions and also in developing fruits thus resulting in increased fruit size and weight (El-Migeed *et al.*, 2013) [24]. A similar increase in fruit weight with the application of putrescine was earlier reported by These results are in agreement with the findings by Shaban *et al.* (2017) [100] in Ewais mango, Ali *et al.* (2017) on mango, El-Migeed *et al.*, (2013) [24] and Naser *et al.* (2016) [79] on date palm and Ataweia *et al.* (2012) [7] on Washington navel orange as they increased fruit weight with the application of putrescine.

Recorded maximum fruit weight (297.04 g) with two layers of brown paper $(B_1)$ whereas control $(B_2)$ recorded minimum fruit weight (254.94 g) (Table 1). This can be attributed to improvement in a microclimate around the fruit bagging would have helped in the increase in fruit weight (Gethe *et al.*, 2021; Kireeti *et al.*, 2016) [31, 59]. Fallahi *et al.* (2001) observed the highest average fruit weight in bagged fruit of ‘BC-2 Fuji’ apple as compared to non-bagged fruit. Debnath and Mitra (2008) [23] found the highest fruit weight in newspaper bags as compared to control in litchi. Watanawan *et al.* (2008) noticed the highest fruit weight in the 2-layer paper bag followed by the paper bag as compared to control in mango cv. ‘Nam Dok Mai’. These results are in agreement with Gethe *et al.* (2021) [31], Hussien *et al.* (1994); Abd El-Rhman (2010) [1] and Samra and Shalan (2013) [96] in pomegranate. Similar results were also reported by Hossain *et al.* (2020), Haldankar *et al.* (2015) [37] and Islam *et al.* (2019) [46] in mango, Wang *et al.* (2007) [119] in Tomato; Purbey and Kumar (2015) [86] and Debnath and Mitra (2008) [23] in litchi and Harshash and Al-Obeed (2010) [5] in date palm and Lal (2019) in guava.

However, no significant difference was found in interaction of bio-regulators and bagging (SxB) in mango cv. Banganpalli.

## 5. Yield per tree (kg)

Maximum fruit yield per tree (42.46 kg) was recorded with application of Ca $(NO_3)$ @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm $(S_4)$ whereas minimum fruit yield per tree (30.99 kg) was recorded in control $(S_5)$ (Table 1). This increase in fruit yield per tree with the application of Ca $(NO_3)$ @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm $(S_4)$ could be attributed to an increase in yield attributing characters *viz*., fruit size (length) and fruit weight (Table 1.) with this treatment under present study. A similar increase in fruit yield was also reported earlier by Vijay Krishna *et al.*, (2012) [116] in mango cv. Banganpalli, Sankar *et al.*, (2013) [97] in Alphonso mango, Jyothi *et al.*, (2018) [50] in mango cv. Langra with calcium nitrate, Notodimedjo. (2000) [82] in Arumanis mango, Kulkarni *et al.*, (2017) [61] in Kesar mango, Gattass *et al.*, (2018) [3] in Keitt mango trees sprayed with CPPU and Shaban *et al.* (2017) [100] on Ewais mango, Buronkar (2005) [19] in Alphonso mango trees, Naser *et al.* (2016) [79] in date palm and Fakir and Abed AL-Hussain (2009) on tomato sprayed with putrescine.

Regarding the effect of bagging treatments (B), bagging with two layers of brown paper $(B_1)$ recorded maximum yield per tree (40.21 kg) whereas control $(B_2)$ recorded minimum fruit yield per tree (32.51 kg) (Table 1). The increased fruit yield could be attributed to an increase in yield attributing characters *viz*., fruit size (length) and fruit weight (Table 1.) with this treatment under the present study. The results are in close agreement with the findings of Gethe *et al.*, (2021) [31] who reported increased fruit size, weight and yield in pomegranate due to bagging. A similar increase in fruit yield with bagging was also reported by El-Wafa (2014) [25] in pomegranate and Nehad, *et al.* (2017) [80] in mango.

However, no significant difference was found in fruit yield per tree among bio-regulators and bagging (SxB) in mango cv. Banganpalli.

## 6. Canopy volume ($m^3$)

The data obtained for the effect of the pre-harvest spray of bio-regulators and bagging on canopy volume ($m^3$) was presented in Table 1. The analysis of pooled data revealed that the application of different bio-regulators (S) and bagging (B) treatment has no significant effect on canopy volume ($m^3$) in mango cv. Banganpalli.

## 7. Fruit yield per $m^3$ canopy volume of the tree (kg)

Maximum fruit yield per $m^3$ canopy volume of the tree (0.81 kg) recorded with the application of Ca ($NO_3$) @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm ($S_4$) whereas minimum fruit yield per $m^3$ canopy volume of the tree (0.58 kg) was recorded in control ($S_5$) (Table 1). This increase in fruit yield per $m^3$ canopy volume of the tree with the application of Ca ($NO_3$) @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm ($S_4$) could be attributed to an increase in yield attributing characters *viz*., fruit size (length) and fruit weight (Table 1.) with this treatment under present study. This is due to cytokinin's are reported to alter sink-source relations, is a promising approach to improve yield attributes, and they regulate important physiological parameters that determine biomass formation and distribution via central genes of primary metabolite pathways, including invertases, hexose transporters and key genes of phosphate and nitrogen metabolism and signalling (Schmülling, 2004, Niederholzer *et al.*, 2006 and Gattass *et al.*, 2018) [99, 81, 30] contributing to increased fruit growth resulting in more yield per $m^3$ canopy volume of the tree. Calcium is involved in the faster mobilization of metabolites in the fruits and cell division and cell expansion, as well as the increase in the volume of intercellular space in mesocarpic cells (Purohit *et al*, 2019) [87] increasing in fruit size and weight and this, led to more yield per $m^3$ canopy volume of tree in the present study with calcium application. Further, the positive impact of polyamine spraying on fruit physical properties was reported by many investigators in fruit crops (Ayad *et al.*, 2011) [8]. This positive impact of putrescine might be attributed to increased nutrient uptake thereby improved fruit set and enhanced metabolic processes such as carbohydrate transport (El-Migeed *et al.*, 2013) [24] resulting in improved fruit size and yield. A similar increase in fruit size and yield was also reported earlier by Notodimedjo. (2000) [82] in Arumanis mango, Kulkarni *et al.*, (2017) [61] in Kesar mango, Gattass *et al.*, (2018) [30] in Keitt mango trees sprayed with CPPU, Shaban *et al.* (2017) [100] on Ewais mango, Buronkar (2005) [19] in Alphonso mango trees, Naser *et al.* (2016) [79] in date palm and Fakir and Abed AL-Hussain (2009) on tomato sprayed with putrescine and Vijay Krishna *et al.*, (2012) [16] in mango cv. Banganpalli, Sankar *et al.*, (2013) [97] in Alphonso mango, Jyothi *et al.*, (2018) [50] in mango cv. Langra with calcium nitrate application.

Regarding the effect of bagging treatments (B), bagging with two layers of brown paper ($B_1$) recorded maximum yield per $m^3$ canopy volume of the tree (0.75 kg) whereas control ($B_2$) recorded minimum fruit yield per $m^3$ canopy volume of the tree (0.63 kg). The increased fruit yield could be attributed to an increase in yield attributing characters *viz*., fruit size (length) and fruit weight (Table 1) with this treatment under the present study. Bagging on fruits alters the microenvironment around fruits (Kireeti *et al.*, 2018; Sharma *et al.*, 2014) [58, 102] and this might have created better conditions for fruit growth and development. The results are in close agreement with the findings of El-Wafa (2014) [25] and Gethe *et al.*, (2021) [31] in pomegranate and Nehad, *et al.* (2017) [80] in mango who reported increased fruit size, weight and yield due to bagging.

However, the interaction effect of the pre-harvest spray of different bio-regulators and bagging (SxB) was found not significant.

## 8. Specific gravity of fruit

Application of Ca ($NO_3$) @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm ($S_4$) has resulted in maximum specific gravity (1.03) which was on par with that of (1.00) resulted with the application of CPPU @ 10 ppm whereas the minimum value for specific gravity (0.93) was recorded in control ($S_5$) (Table 2). This increase in specific gravity of fruit with application of Ca ($NO_3$) @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm ($S_4$) could be attributed to increased individual fruit weight (Table 1) in present treatment. Similar improvements in fruit weight and fruit quality were also reported by Sankar *et al.*, (2013) [97] in Alphonso mango and Jyothi *et al.*, (2018) [50] in mango cv. Langra with the application of Ca $(NO_3)_2$ Kumar *et al.*, (2013) in apple cv. Red delicious, Kulkarni *et al.*, (2017) [61] in Kesar mango and Gattass *et al.*, (2018) [30] in Keitt mango trees with CPPU application and Shaban *et al.* (2017) [100] in Ewais mango, Ali *et al.* (2017) on mango, El-Migeed *et al.*, (2013) [24] and Naser *et al.* (2016) [79] on date palm and Ataweia *et al.* (2012) [7] on Washington navel orange with putrescine application.

Regarding the effect of bagging treatments (B), bagging with two layers of brown paper ($B_1$) recorded maximum specific gravity (1.02) whereas control ($B_2$) recorded minimum specific gravity (0.96). The improvement in the fruit quality may be due to the environment created inside by the bagging material that plays a significant role in the growth and development of fruits (Sharma *et al.*, 2014) [102]. The increased specific gravity of fruits in the present study could be due to the increased fruit size (Table 1) and individual fruit weight (Table 1) with the bagging of fruits over control treatment. These results are in agreement with Hossain *et al.* (2020), Haldankar *et al.* (2015) [37] and Islam *et al.* (2019) [46] in mango, Gethe *et al.* (2021) [31], Hussien *et al.* (1994); Abd El-Rhman (2010) [1] and Samra and Shalan (2013) [96] in pomegranate who reported increased fruit weight and fruit quality with bagging.

However, the interaction effect of the pre-harvest spray of different bio-regulators and bagging (SxB) was found not significant on the specific gravity of fruits.

## 9. Fruit TSS ($^0$Brix)

The maximum fruit TSS (17.73 $^0$Brix) was recorded with the application of Ca ($NO_3$) @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm ($S_4$) whereas control ($S_5$) recorded minimum fruit TSS (15.64 $^0$Brix) (Table 2). The higher TSS content with CPPU application might be attributed to a higher rate of photosynthates assimilation, as cytokinin are known to influence sink-source relations by mobilization of metabolites and nutrients to the developing fruits (Leopold and Kriedemann, 1975; Banyal and Banyal, 2020) [69, 12]. The results of the present study are in conformity with the studies conducted by Kim *et al.*, (2006) [57] on kiwi fruit and Barkule *et al.* (2018) [13] on sapota who reported that foliar application of CPPU increased the fruit TSS content. The increase in TSS with Ca $(NO_3)_2$ application may be attributed to the conversion of starch and other polysaccharides into soluble forms of sugars (Mukherjee and Dutta, 1967). A similar increase in TSS with Ca $(NO_3)_2$ was earlier reported by Bhatt *et al.*, (2012) [114] in Dashehari mango and Sankar *et al.*, (2013) [97] in mango cv. Alphonso. The increased TSS of fruits with putrescine could be attributed to improved fruit growth and nutrient uptake that accelerated metabolic processes and sugar transport to actively growing regions and developing fruits (El-Migeed *et al.*, 2013) [24]. These results are in agreement with the findings by Ali *et al.* (2017) on mango, Naser *et al.* (2016) [79] and El-Migeed *et al.*, (2013) [24] on date palm and Ataweia *et al.* (2012) [7] on Washington navel orange who reported increased fruit TSS with the application of putrescine.

Regarding the effect of bagging treatments (B) on fruit TSS ($^0$Brix), no significant difference was found among the treatments (Table 2).

Regarding the interaction effect of the pre-harvest spray of different bio-regulators and bagging (SxB), on fruit TSS ($^0$Brix), maximum TSS (18.47 $^0$Brix) was recorded with a pre-harvest spray of Ca $(NO_3)$ @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm followed by bagging with two layers of brown paper ($S_4B_1$) whereas the control treatment (no chemical spray and no bagging) ($S_5B_2$) recorded minimum TSS (15.54 $^0$Brix) of fruits (Table 2). From the results, it is evident that the individual effect of bagging treatment did not influence the fruit TSS but the synergistic effect of bagging and pre-harvest sprays has significantly influenced the fruit TSS. This could be attributed to the improved fruit growth and nutrient uptake with accelerated metabolic processes and sugar transport to the developing fruits due to the pre-harvest spray of Ca $(NO_3)$ @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm and congenial microclimate created by the bagging treatment for fruit growth and development. These results are in close agreement with the findings of Jakhar and Pathak (2016) [47] who reported maximum TSS content of fruits with a pre-harvest spray of 2% $CaCl_2$+1% $K_2SO_4$ followed by bagging with brown paper bags in mango cv. Amrapali.

## 10. Reducing and non-reducing sugars (%)

The application of Ca $(NO_3)$ @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm ($S_4$) has resulted in maximum reducing sugars (2.86%) and non-reducing sugars (8.31%) whereas control ($S_5$) recorded minimum reducing sugars (2.56%) and non-reducing sugars (7.66%) (Table 2). Calcium or nitrogen elements might be involved in hydrolytic enzymes activation which led to the conversion of carbohydrates into simple sugars (Sankar *et al.*, 2013) [97]. The present results were in conformity with earlier findings of Bhatt *et al.*, (2012) [14] in Dashehari mango with the application of Ca $(NO_3)_2$ and Bushan *et al.*, (2015) in Amrapali mango trees applied with Ca $(NO_3)_2$. The higher sugar content with CPPU might be attributed to a higher rate of photosynthates assimilation, as cytokinins are known to influence the mobilization of metabolites and nutrients to the cytokinin treated portion of the plant (Leopold and Kriedemann, 1975) [69]. The results of the present study are in conformity with the studies conducted by Babita and Rana (2015) [9] and Kim *et al.*, (2006) [57] on kiwi fruit and Barkule *et al.* (2018) [13] on sapota who reported increased sugar content with CPPU. The increased sugars of fruits with putrescine could be attributed to improved nutrient uptake and sugar transport to actively growing regions and developing fruits during fruit development (El-Migeed *et al.*, 2013) [24]. Similar results were reported by El-Migeed *et al.*, (2013) [24] on date palm with putrescine application.

Regarding the effect of bagging treatments (B) on reducing and non-reducing sugars, bagging with two layers of brown paper ($B_1$) recorded maximum reducing sugars (2.81%) and non-reducing sugars (8.09%) whereas control ($B_2$) recorded minimum reducing sugars (2.64%) and non-reducing sugars (7.90%) (Table 2). This is due to the congenial microclimate around the fruit with bagging treatment and conversion of starch into simple sugars resulting in increased reducing sugars and non-reducing sugars (Jakhar and Pathak, 2016; Banday, 1996) [47] during subsequent growth and development stages of fruit. A similar increase in reducing and non-reducing sugars of fruits due to bagging was earlier reported by Jakhar and Pathak, (2016) [47] in mango cv. Amrapali, Islam *et al.*, (2017) [45] in mango cv. Mishribhog and Akter *et al.*, (2020) [3] in mango cv. Amrapali.

However, the interaction effect of the pre-harvest spray of different bio-regulators and bagging (SxB) has recorded no significant differences in reducing and non-reducing sugars (%) among the treatments.

## 11. Total sugars (%)

The maximum (11.16%) total sugar was recorded with the application of Ca $(NO_3)$ @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm ($S_4$) and control ($S_5$) recorded minimum total sugars (10.17%) (Table 2). During the ripening process of fruits activation of hydrolytic enzymes which aid in the conversion of starch, hemicelluloses and organic acids into various forms of sugars, α-amylase is one of the hydrolytic enzymes, which involves in the breakdown of the glucosidic linkage of starch (Glasson, 1970) [33]. Calcium or nitrogen elements might be involved in hydrolytic enzymes activation which led to the conversion of carbohydrates into simple sugars (Sankar *et al.*, 2013) [97]. The higher sugar content with CPPU might be attributed to a higher rate of photosynthates assimilation, as cytokinin are known to influence the mobilization of metabolites and nutrients to the cytokinin treated portion of the plant (Leopold and Kriedemann, 1975) [69]. Further, putrescine treatment was reported to increase the nutrient status of foliage and flowers especially N and B (Callan *et al.*, 1978 and Crisosto *et al.*, 1988) [21, 22] in pear. This improvement in nutrient status might have increased the rate of sugar transport to actively growing regions and developing fruits during fruit development (El-Migeed *et al.*, 2013) [24] resulting in increased sugar content of fruits in the present study. These might be possible reasons behind the increase in total sugars content of fruits with $M_4$ treatment used in the present investigation. A similar line of findings was earlier reported by Sankar *et al.*, (2013) [97] mango cv. Alphonso with the application of Ca $(NO_3)_2$, Walid *et al.*, (2015) [118] in Anna apple with the application of potassium and calcium mineral elements, Babita and Rana (2015) [9] and Kim *et al.*, (2006) [57] on kiwi fruit and Barkule *et al.* (2018) [13] on sapota with CPPU application, El-Migeed *et al.*, (2013) [24] on date palm and Ayad *et al.* (2011) [8] on olive with putrescine application.

Regarding the effect of bagging treatments (B) on total sugars (%) of fruit, bagging with two layers of brown paper ($B_1$) recorded the maximum total sugars (10.88%) whereas control ($B_2$) recorded the minimum total sugars (10.55%) (Table 2). This increase in the sugars content of fruits during storage might be because of an increase in reducing sugars and non-reducing sugars (Tables 2) resulting from the conversion of

starch into simple sugars (Jakhar and Pathak, 2016; Banday, 1996) [47]. These results are in conformity with the findings of Akter *et al.*, (2020) [3] in mango cv. Amrapali, Jakhar and Pathak, (2016) [47] in mango cv. Amrapali, Islam *et al.*, (2017) in mango cv. Mishribhog and Nagaharshitha *et al.*, (2014) in mango cv. Alphonso reported increased total sugar content of fruits with bagging.
However, the effect of bagging treatment (B) and the interaction effect of the pre-harvest spray of different bio-regulators and bagging (S x B) was found not significant.

**12. Titratable acidity (%)**
The perusal of the pooled data revealed that the individual effect of the pre-harvest spray of different bio-regulators (S) and bagging treatment (B) along with their interaction (S x B) has resulted in no significant difference in titratable acidity (%) of fruits among the treatments (Table 2).

**13. TSS/Acidity ratio**
The perusal of the pooled data revealed that the individual effect of a pre-harvest spray of different bio-regulators (S) and bagging treatment (B) along with their interaction (S x B) has resulted in no significant difference in the TSS/acidity ratio of fruits among the treatments (Table 2).

**14. Fruit ascorbic acid (mg/100 g. F.W.)**
The application of Ca ($NO_3$) @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm ($S_4$) has resulted in maximum fruit ascorbic acid (18.35 mg/100 g. F.W.) whereas minimum (16.29 mg/100 g. F.W.) was recorded in control ($S_5$). This increase in the ascorbic acid content of fruits in the present treatment is mainly attributed to the application of calcium nitrate. This might be due to calcium compounds bind with the membrane and increase its stability, therefore, they prevent free radicals and reactive oxygen species from connecting to the membrane and contribute to the maintenance of the health of biological membranes (Veltman *et al.*, 2000) [114]. Additionally, calcium compounds cause a delay in the rapid oxidation of ascorbic acid by increasing the activity of ascorbate peroxidase (APX) (Zeraatgar *et al.*, 2018) [125]. Activities of oxidizing enzymes might be reduced with Ca $(NO_3)_2$ resulting in the higher ascorbic acid content of fruits (Goutam *et al.*, 2010) [34]. This finding is in agreement with those of Singh (1988), Ahmed and Singh (2000) and Singh *et al.* (2008) in guava, mango and ber fruits, respectively. Further, the application of polyamines (putrescine) may have inhibited ascorbate oxidase activities, which is responsible for the degradation of ascorbic acid (Malik and Singh, 2006.). A similar increase in fruit ascorbic acid content of fruits was reported by Bhatt *et al.*, (2012) [14] in Dashehari mango, Zeraatgar *et al.*, (2018) [125] in fresh jujube fruit and Walid *et al.*, (2015) [118] in “Le Conte” pear with the application of Ca $(NO_3)_2$ and Venu and Ramdevputra, (2018) on mango cv. Kesar with putrescine application and Malik and Singh (2006) in mango with the application of polyamines reported that putrescine was effective in improving fruit quality of ripe fruit.
Regarding the effect of bagging treatments (B), bagging with two layers of brown paper ($B_1$) recorded maximum fruit ascorbic acid (18.03 mg/100 g. F.W.) whereas control ($B_2$) recorded minimum fruit ascorbic acid (16.92 mg/100 g. F.W.) (Table 2). These results are strongly supported by the findings of Akter *et al.*, (2020) [3] who reported that the fruits bagged with the brown paper bag are not directly exposed to the sunlight which ensures higher xanthophylls content therefore, stored more ascorbic acid than unbagged control in mango cv. Amrapali. A similar increase in the ascorbic acid content of bagged fruits was reported by Islam *et al.*, (2017) [45] in mango cv. Mishribhog, Hongxia *et al.*, (2009) [42] in Zill mango, Haldankar *et al.*, (2015) [37] in mango cv. Alphonso and Sharma *et al.*, (2013) [101] in apple cv. Delicious.
However, the interaction of pre-harvest spray of different bio-regulators and bagging (SxB) has shown no significant effect on fruit ascorbic acid among the treatments.

**15. Shelf life of fruits (days)**
Maximum shelf life of fruits (12.43 days) was recorded with the application of Ca ($NO_3$) @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm ($S_4$) whereas minimum shelf life (8.95 days) was recorded in control ($S_5$) (Table 2). Calcium compounds extend the shelf-life of fruits by maintaining firmness, minimizing the rate of respiration, protein breakdown and disintegration of tissues (Bangerth *et al.*, 1972; Purohit *et al.*, 2019) [87]. Calcium decreases the loss of weight by the maintenance of the fruit firmness, retardation of respiratory rate and delayed senescence (Yadav *et al.* 2009; Purohit *et al.*, 2019) [87]. Calcium, as a constituent of the cell wall, plays an important role in forming cross-bridges, which influence cell wall strength and are regarded as the last barrier before cell separation (Fry, 2004). Another possible reason might be that calcium nitrate has been reported in the literature to delay the ripening and senescence in fruits by lowering the respiration rate (Singh *et al.* 1993; Singh *et al.* 2017) [106]. CPPU, which is a synthetic cytokinin, is used to extend the shelf and storage life of fruits especially in grapes (Marzouk and Kassem, 2011) [71]. 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) [13]. Further, the possible reasons for increased shelf life by the application of putrescine could be due to delayed changes associated with the senescence such as ethylene production, browning, peroxide level and cell leakage (Jiang and Chen, 1995) [48] and retardation of fruit softening due to the inhibition of polygalacturonase activities, presumably through binding to pectic substances (Kramer *et al.*, 1989; Venu and Ramdevputra, 2018) [60]. A similar increase in the shelf life of fruits was reported earlier by Purohit *et al.* (2019) [87] in guava cv. L-49, Singh *et al.* (2017) in mango cv. Dashehari, Romero-Gomezcana, *et al.* (2006) [94] with mango cv. 'Haden', Singh, *et al.* (1998) [108] with mango cv. Amrapali with calcium application, Barkule *et al.*, (2018) [13] in sapota cv. Kalipatti and Al-Obeed (2011) [5] in grape with CPPU application and Venu and Ramdevputra, (2018) in mango cv. Kesar, Malik and Singh (2006) in mango cv Kensington Pride, Khan and Singh (2008) [54] in plum, Mirdehghan *et al.*, (2013) in pistachio nut and Mirdehghan *et al.*, (2013) in grape with putrescine application.
Regarding the effect of bagging treatments (B), bagging with two layers of brown paper ($B_1$) recorded the maximum shelf life (11.90 days) whereas control ($B_2$) recorded minimum shelf life (10.02 days) of fruits (Table 2). This could be due to bagging modified the microenvironment near fruit especially with respect to temperature and humidity. Bagging provided a physical barrier between fruit and pests (Islam *et al.*, 2017) [45] and save fruits from pesticides residues, blemishes, sunburn

and pests (Karar *et al.*, 2019) resulting in better growth and development of fruits with improved quality. These are the possible reasons for an improved shelf life of mango fruits with bagging treatment in the present study. These results are strongly supported by the findings of Akter *et al.*, (2020) [3] who recorded increased shelf life of fruits of mango cv. Amrapali bagged with brown paper bags and they reported that brown paper bags shown the maximum shelf life because, these bagged fruits are always dry, healthy and have no chance for disease and insect infestation. Islam *et al.* (2017) [45] also reported that pre-harvest bagging delayed ripening resulting in the extended shelf life of mango cv. Mishribhog. Further, Islam *et al.* (2019) [46] reported that fruits with brown paper bagging shown increased shelf life with lowest weight loss and good physical quality over unbagged fruits (control) through diminution in disease and insect-pest infestation and shelf life of mango cv. Langra. The longer shelf life of bagged fruits indicated that the effect of bagging persisted after ripening. A similar increase in the shelf life of fruits with bagging was also reported earlier by Jakhar and Pathak (2016) [47] in mango cv. Amrapali. Signes *et al.* (2007) [103] also reported that pre-harvest bagging delayed ripening resulting in the extended shelf life of 'Perla', a black table-grape.

Further, regarding the interaction effect of the pre-harvest spray of different bio-regulators and bagging (SxB), the maximum shelf life of fruits (12.97 days) was recorded with a pre-harvest spray of Ca ($NO_3$) @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm followed by bagging with two layers of brown paper ($S_4B_1$) whereas the control treatment (no chemical spray and no bagging) ($S_5B_2$) recorded minimum shelf life of fruits (8.15 days) (Table 2). The combined application of pre-harvest spray of Ca ($NO_3$) @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm followed by bagging with two layers of brown paper ($S_4B_1$) has synergistically increased shelf life over control and their application. Cell wall integrity maintenance nature of Ca $(NO_3)_2$, the anti-senescence role of CPPU, delayed changes associated with the senescence and retardation of fruit softening due to putrescine application and congenial microclimate created by bagging with protection from sunscald, pests and diseases have resulted in better growth and development with an increased shelf life of fruits. Similar results of increased shelf life with pre-harvest chemical spray and bagging were reported by Jakhar and Pathak (2016) [47] who reported increased shelf life of mango cv. Amrapali treated with 2% $CaCl_2$+1% $K_2SO_4$+bagging over control.

## 16. Organoleptic characters of fruits

Regarding the effect of the pre-harvest spray of different bio-regulators (S), application of Ca ($NO_3$) @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm ($S_4$) has resulted in fruits with good organoleptic characters attaining the highest score for all recorded characters *viz*., colour (8.68), texture (8.13), flavour (8.38), taste (8.34) and overall acceptance (8.38) whereas fruits from the control treatment ($S_5$) attained lowest scores for colour (6.83), texture (6.40), flavour (6.32), taste (6.64) and overall acceptance (6.55) (Table 3). Regarding the effect of bagging treatments (B), bagging with two layers of brown paper ($B_1$) resulted in fruits with good organoleptic characters attaining the highest score for all recorded characters *viz*., colour (8.39), texture (7.87), flavour (8.06), taste (8.08) and overall acceptance (8.10) whereas fruits from the control treatment ($S_5$) attained lowest scores for colour (7.40), texture (6.93), flavour (6.96), taste (7.16) and overall acceptance (7.11) (Table 3). Further, regarding the interaction effect of the pre-harvest spray of different bio-regulators and bagging (SxB) on organoleptic characters of fruits, the pre-harvest spray of Ca ($NO_3$) @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm and bagging with two layers of brown paper ($S_4B_1$) has resulted in fruits with good organoleptic characters attaining highest score for all recorded characters *viz*., colour (8.96), texture (8.40), flavour (8.70), taste (8.60) and overall acceptance (8.66) whereas fruits from the control treatment ($S_5$) attained lowest scores for colour (6.40), texture (6.00), flavour (5.85), taste (6.25) and overall acceptance (6.12) (Table 3).

The treatment pre-harvest spray of Ca ($NO_3$) @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm has led to improved fruit size, fruit weight (Table 1), TSS, total sugars, ascorbic acid resulting in good quality fruits with increased shelf life. The increased fruit size due to more dry matter accumulation, uniform colour development, more firmness, increased fruit TSS and total sugars improved the appearance, flavour and sweetness of fruit resulting in better taste and texture of fruits with overall acceptance. This improved physical, chemical and quality attributes of fruits with a pre-harvest spray of Ca ($NO_3$) @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm resulted in fruits attaining the highest scores for all evaluated organoleptic characters in the present study. These results are in conformity with the findings of Jakhar and Pathak (2016) [47] who reported that fruits treated with 2% $CaCl_2$+1% $K_2SO_4$+bagging were significantly superior in organoleptic quality. Bagging treatments had a significant effect on fruit appearance as it protects fruits from insects, sunburn, uneven colouring resulted from strong sunshine (Wu *et al.*, 2013) and it improved the fruit surface promoting the fruit colour when fruit was ripe. This is attributed to the decrease in green skin due to degradation of skin chlorophyll with reduced light intensity from bagging (Hofman *et al.*, 1997) [41]. Bagging on the other hand changed the micro-environment of the bagged fruit and increased fruit size, weight, the sugar content of fruits (Table 2) improving the taste, texture and flavour in the present study resulting in good acceptability of fruits. These results are in agreement with the findings of Jakhar and Pathak (2016) [47] who reported that pre-harvest spray of 2% $CaCl_2$+1% $K_2SO_4$ followed by bagging with brown paper bags resulted in best quality fruits superior in organoleptic quality with good acceptability. Hayat *et al.* (2003) [44] reported that the pre-harvest treatment of 2% $CaCl_2$ on apple *cv*. Banky retained the best general appearance, organoleptic quality, and consumer acceptability during storage. Similarly, Sharma *et al.* (2013) [101] reported that the preharvest bagging improved the visual quality of fruit by promoting skin colouration and reducing blemishes, it also changed the micro-environment for fruit development resulting in improved fruit quality in apple cv. Delicious.

## Summery and Conclusion

Among different bio-regulators, the pre-harvest spray of Ca $(NO_3)_2$ @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm ($S_4$) has shown significant influence on fruit growth and development and recorded early harvesting with the minimum number of days taken for the maturity of the fruit and it also recorded maximum fruit length and fruit weight with maximum yield per tree and unit ($m^3$) canopy volume. In case of different bagging treatments on fruit growth and development, bagging with two layers of brown paper ($B_1$) has resulted in early harvesting with the minimum number of days taken for the maturity of the fruit, maximum fruit size (length and breadth) and weight, maximum yield per tree and yield per unit ($m^3$) canopy volume. However, the interaction effect of Ca $(NO_3)_2$ @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm and bagging with two layers of brown paper ($S_4B_1$) resulted in the highest fruit TSS with maximum shelf life of fruits, best quality attaining highest score for all organoleptic characters evaluated (*viz*., colour, texture, flavour, taste and overall acceptance). Thus, it can be concluded that pre harvest spray of Ca $(NO_3)_2$ @ 1% + Putrescine @ 0.1mM + CPPU @ 10 ppm fallowed by two layers of brown paper ($S_4B_1$) bagging may be recommended to get superior yield and quality of fruits mango cv. Banganpalli.

**Table 1:** Effect of pre-harvest spray of bio-regulators and bagging on physical and yield parameters of mango (*Mangifera indica* L.) cv. Banganpalli

| Treatments | Number of days taken from fruit set to maturity | | | Number of fruits per tree at the time of harvest | | | Fruit length (cm) at the time of harvest | | | Fruit breadth (cm) at the time of harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | POOLED | | | POOLED | | | POOLED | | | POOLED | | |
| | $B_1$ | $B_2$ | Mean of S | $B_1$ | $B_2$ | Mean of S | $B_1$ | $B_2$ | Mean of S | $B_1$ | $B_2$ | Mean of S |
| $S_1$ | 136.66 | 147.25 | 141.96$^{b}$ | 128.79 | 122.01 | 125.4 | 8.52 | 8.42 | 8.47$^{b}$ | 7.68 | 7.49 | 7.59 |
| $S_2$ | 133.14 | 150.78 | 141.96$^{b}$ | 122.49 | 122.17 | 122.33 | 8.74 | 8.46 | 8.60$^{b}$ | 7.64 | 7.5 | 7.57 |
| $S_3$ | 126.08 | 140.19 | 133.14$^{a}$ | 139.6 | 125.52 | 132.56 | 8.73 | 8.49 | 8.61$^{a}$ | 7.64 | 7.35 | 7.5 |
| $S_4$ | 122.55 | 129.61 | 126.08$^{a}$ | 148.64 | 138.71 | 143.67 | 9 | 8.66 | 8.83$^{a}$ | 7.89 | 7.39 | 7.64 |
| $S_5$ | 143.72 | 154.3 | 149.01$^{b}$ | 126.62 | 114.64 | 120.63 | 8.57 | 8.37 | 8.47$^{b}$ | 7.5 | 7.34 | 7.42 |
| Mean of B | 129.61$^{a}$ | 141.96$^{b}$ | 135.78 | 134.88 | 127.1 | 130.99 | 8.75$^{a}$ | 8.51$^{b}$ | 8.63 | 7.71$^{a}$ | 7.43$^{b}$ | 7.57 |
| | SEm± | C.D. at 5% | | SEm± | C.D. at 5% | | SEm± | C.D. at 5% | | SEm± | C.D. at 5% | |
| S | 2.76 | 8.19 | | 5.52 | NS | | 0.07 | 0.22 | | 0.06 | NS | |
| B | 1.74 | 5.18 | | 3.49 | NS | | 0.05 | 0.14 | | 0.04 | 0.11 | |
| SXB | 3.9 | NS | | 7.8 | NS | | 0.1 | NS | | 0.08 | NS | |

| Treatments | Fruit weight (g) | | | Yield (kg) per tree | | | canopy volume ($m^3$) | | | Fruit yield per $m^3$ canopy volume of tree (kg) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | POOLED | | | POOLED | | | POOLED | | | POOLED | | |
| | $B_1$ | $B_2$ | Mean of S | $B_1$ | $B_2$ | Mean of S | $B_1$ | $B_2$ | Mean of S | $B_1$ | $B_2$ | Mean of S |
| $S_1$ | 288.69 | 242.91 | 265.80$^{b}$ | 37.24 | 29.71 | 33.47$^{b}$ | 56.96 | 47.77 | 52.36 | 0.67 | 0.62 | 0.64$^{b}$ |
| $S_2$ | 282.72 | 255.01 | 268.86$^{b}$ | 34.62 | 31.16 | 32.89$^{b}$ | 51.55 | 47.78 | 49.67 | 0.67 | 0.65 | 0.66$^{b}$ |
| $S_3$ | 295.06 | 254.65 | 274.86$^{b}$ | 41.21 | 32.04 | 36.62$^{b}$ | 55.66 | 56.65 | 56.15 | 0.74 | 0.56 | 0.65$^{b}$ |
| $S_4$ | 321.68 | 267.18 | 294.43$^{a}$ | 47.78 | 37.14 | 42.46$^{a}$ | 51.72 | 52.71 | 52.21 | 0.92 | 0.7 | 0.81$^{a}$ |
| $S_5$ | 276.52 | 236.49 | 256.51$^{c}$ | 35.1 | 26.89 | 30.99$^{c}$ | 53.69 | 54.68 | 54.18 | 0.66 | 0.49 | 0.58$^{b}$ |
| Mean of B | 297.04$^{a}$ | 254.94$^{b}$ | 275.99 | 40.21$^{a}$ | 32.51$^{b}$ | 36.36 | 53.97 | 51.22 | 52.6 | 0.75$^{a}$ | 0.63$^{b}$ | 0.69 |
| | SEm± | C.D. at 5% | | SEm± | C.D. at 5% | | SEm± | C.D. at 5% | | SEm± | C.D. at 5% | |
| S | 3.78 | 11.23 | | 1.72 | 5.11 | | 1.51 | NS | | 0.03 | 0.1 | |
| B | 2.39 | 7.1 | | 1.09 | 3.23 | | 0.96 | NS | | 0.02 | 0.06 | |
| SXB | 5.34 | NS | | 2.43 | NS | | 2.14 | NS | | 0.05 | NS | |

*Figures with same alphabet did not differ significantly

$S_1$ - Ca $(NO_3)_2$ @ 1%
$S_2$ - Putrescine@ 0.1mM
$S_3$- CPPU @ 10 ppm (1-(2- Chloro-4-Pyridyl)-3-Phenyl Urea)
$S_4$ - Ca $(NO_3)_2$ @ 1%+ Putrescine @ 0.1mM+ CPPU @ 10 ppm
$S_5$ - Control (no chemical spray)

$B_1$ - Two layers of brown paper
$B_2$ - No bagging

**Table 2:** Effect of pre-harvest spray of bio-regulators and bagging on bio chemical characters of mango (*Mangifera indica* L.) cv. Banganpalli

| Treatments | Specific gravity | | | TSS ($^0$Brix) | | | Reducing sugars (%) | | | Non-reducing sugars (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | POOLED | | | POOLED | | | POOLED | | | POOLED | | |
| | $B_1$ | $B_2$ | Mean of S | $B_1$ | $B_2$ | Mean of S | $B_1$ | $B_2$ | Mean of S | $B_1$ | $B_2$ | Mean of S |
| $S_1$ | 0.99 | 0.94 | 0.96$^{b}$ | 16.60$^{c}$ | 16.28$^{d}$ | 16.44$^{b}$ | 2.67 | 2.66 | 2.66$^{bc}$ | 7.99 | 7.72 | 7.85$^{c}$ |
| $S_2$ | 1 | 0.93 | 0.96$^{b}$ | 16.89$^{b}$ | 16.27$^{d}$ | 16.58$^{b}$ | 2.83 | 2.64 | 2.73$^{ab}$ | 8.07 | 8.03 | 8.05$^{b}$ |
| $S_3$ | 1.03 | 0.97 | 1.00$^{a}$ | 16.17$^{d}$ | 15.75 | 15.96$^{c}$ | 2.74 | 2.55 | 2.65$^{bcd}$ | 7.93 | 7.63 | 7.78$^{cd}$ |
| $S_4$ | 1.05 | 1.02 | 1.03$^{a}$ | 18.47$^{a}$ | 16.99$^{b}$ | 17.73$^{a}$ | 3 | 2.72 | 2.86$^{a}$ | 8.38 | 8.24 | 8.31$^{a}$ |
| $S_5$ | 0.96 | 0.91 | 0.93$^{b}$ | 15.73 | 15.54 | 15.64$^{d}$ | 2.63 | 2.5 | 2.56$^{bcde}$ | 7.71 | 7.62 | 7.66 |
| Mean of B | 1.02$^{a}$ | 0.96$^{b}$ | 0.99 | 17.03 | 16.32 | 16.68 | 2.81$^{a}$ | 2.64$^{b}$ | 2.72 | 8.09$^{a}$ | 7.90$^{b}$ | 8 |
| | S.Em± | C.D. at 5% | | S.Em± | C.D. at 5% | | S.Em± | C.D. at 5% | | S.Em± | C.D. at 5% | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | 0.01 | 0.04 | | 0.03 | 0.1 | | 0.05 | 0.16 | | 0.04 | 0.12 | |
| **B** | 0.01 | 0.02 | | 0.02 | NS | | 0.03 | 0.1 | | 0.03 | 0.08 | |
| SXB | 0.02 | NS | | 0.05 | 0.14 | | 0.08 | NS | | 0.06 | NS | |

| Treatments | Total sugars (%) | | | Acidity (%) | | | TSS/Acidity | | | Ascorbic acid (mg/100 g. F.W.) | | | Shelf life | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **POOLED** | | | **POOLED** | | | **POOLED** | | | **POOLED** | | | **POOLED** | | |
| | **$B_1$** | **$B_2$** | **Mean of S** | **$B_1$** | **$B_2$** | **Mean of S** | **$B_1$** | **$B_2$** | **Mean of S** | **$B_1$** | **$B_2$** | **Mean of S** | **$B_1$** | **$B_2$** | **Mean of S** |
| $S_1$ | 10.65 | 10.38 | $10.52^c$ | 0.42 | 0.49 | 0.45 | 39.53 | 35.05 | 37.29 | 17.4 | 16.45 | $16.92^c$ | 10.83e | 9.22 | $10.02^c$ |
| $S_2$ | 10.9 | 10.66 | $10.78^b$ | 0.49 | 0.55 | 0.52 | 33.62 | 29.54 | 31.58 | 17.72 | 16.13 | $16.92^c$ | $11.36^d$ | 8.69 | $10.02^c$ |
| $S_3$ | 10.57 | 10.2 | $10.38^d$ | 0.45 | 0.49 | 0.47 | 36.66 | 32.81 | 34.74 | 18.35 | 17.08 | $17.71^b$ | $12.43^b$ | 10.29 | $11.36^b$ |
| $S_4$ | 11.38 | 10.95 | $11.16^a$ | 0.47 | 0.51 | 0.49 | 40.47 | 34.31 | 37.39 | 18.67 | 18.03 | $18.35^a$ | $12.97^a$ | $11.90^c$ | $12.43^a$ |
| $S_5$ | 10.25 | 10.09 | $10.17^e$ | 0.49 | 0.49 | 0.49 | 33.62 | 35.41 | 34.51 | 16.77 | 15.82 | $16.29^d$ | 9.76 | 8.15 | $8.95^d$ |
| Mean of B | $10.88^b$ | $10.55^a$ | 10.71 | 0.45 | 0.51 | 0.48 | 37.57 | 32.93 | 35.25 | $18.03^a$ | $16.92^b$ | 17.48 | $11.90^a$ | $10.02^b$ | 10.96 |
| | SEm± | C.D. at 5% | | SEm± | C.D. at 5% | | SEm± | C.D. at 5% | | SEm ± | C.D. at 5% | | SEm± | C.D. at 5% | |
| S | 0.04 | 0.13 | | 0.03 | NS | | 2.08 | NS | | 0.16 | 0.49 | | 0.11 | 0.33 | |
| B | 0.03 | 0.08 | | 0.02 | NS | | 1.32 | NS | | 0.1 | 0.31 | | 0.07 | 0.21 | |
| SXB | 0.06 | NS | | 0.04 | NS | | 2.94 | NS | | 0.23 | NS | | 0.16 | 0.47 | |

**Figures with same alphabet did not differ significantly*

$S_1$ - Ca $(NO_3)_2$ @ 1%
$S_2$ - Putrescine@ 0.1mM
$S_3$- CPPU @ 10 ppm (1-(2- Chloro-4-Pyridyl)-3-Phenyl Urea)
$S_4$ - Ca $(NO_3)_2$ @ 1%+ Putrescine @ 0.1mM+ CPPU @ 10 ppm
$S_5$ - Control (no chemical spray)

$B_1$ - Two layers of brown paper
$B_2$ - No bagging

**Table 3:** Effect of pre-harvest spray of bio-regulators and bagging on organoleptic characters of mango (*Mangifera indica* L.) cv. Banganpalli

| **Treatments** | **Colour score** | | | **Texture score** | | | **Flavour score** | | | **Taste score** | | | **Overall acceptance score** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **POOLED** | | | **POOLED** | | | **POOLED** | | | **POOLED** | | | **POOLED** | | |
| | **$B_1$** | **$B_2$** | **Mean of S** | **$B_1$** | **$B_2$** | **Mean of S** | **$B_1$** | **$B_2$** | **Mean of S** | **$B_1$** | **$B_2$** | **Mean of S** | **$B_1$** | **$B_2$** | **Mean of S** |
| $S_1$ | 7.82 | 6.97 | $7.40^c$ | 7.33 | 6.53 | $6.93^c$ | 7.43 | 6.48 | $6.96^c$ | 7.56 | 6.77 | $7.16^c$ | 7.54 | 6.69 | $7.11^c$ |
| $S_2$ | $8.11^b$ | 6.68 | $7.40^c$ | $7.60^b$ | 6.27 | $6.93^c$ | $7.75^b$ | 6.17 | $6.96^c$ | $7.82^b$ | 6.51 | $7.16^c$ | $7.82^d$ | 6.41 | $7.11^c$ |
| $S_3$ | $8.68^a$ | 7.54 | $8.11^b$ | $8.13^a$ | 7.07 | $7.60^b$ | $8.38^a$ | 7.11 | $7.75^b$ | $8.34^a$ | 7.29 | $7.82^b$ | $8.38^b$ | 7.25 | $7.82^b$ |
| $S_4$ | $8.96^a$ | $8.39^{ab}$ | $8.68^a$ | $8.40^a$ | $7.87^{ab}$ | $8.13^a$ | $8.70^a$ | $8.06^{ba}$ | $8.38^a$ | $8.60^a$ | $8.08^{ba}$ | $8.34^a$ | $8.66^a$ | $8.10^c$ | $8.38^a$ |
| $S_5$ | 7.25 | 6.4 | $6.83^d$ | 6.8 | 6 | $6.40^d$ | 6.8 | 5.85 | $6.32^d$ | 7.03 | 6.25 | $6.64^d$ | 6.97 | 6.12 | $6.55^d$ |
| Mean of B | $8.39^a$ | $7.40^b$ | 7.89 | $7.87^a$ | $6.93^b$ | 7.4 | $8.06^a$ | $6.96^b$ | 7.51 | $8.08^a$ | $7.16^b$ | 7.62 | $8.10^a$ | $7.11^b$ | 7.61 |
| | SEm ± | C.D. at 5% | | SEm ± | C.D. at 5% | | SEm ± | C.D. at 5% | | SEm ± | C.D. at 5% | | SEm ± | C.D. at 5% | |
| S | 0.08 | 0.23 | | 0.08 | 0.25 | | 0.08 | 0.25 | | 0.07 | 0.2 | | 0.03 | 0.09 | |
| B | 0.05 | 0.15 | | 0.05 | 0.16 | | 0.05 | 0.16 | | 0.04 | 0.13 | | 0.02 | 0.06 | |
| SXB | 0.11 | 0.32 | | 0.12 | 0.35 | | 0.12 | 0.35 | | 0.1 | 0.28 | | 0.04 | 0.13 | |

*Figures with same alphabet did not differ significantly

$S_1$ - Ca $(NO_3)_2$ @ 1%
$S_2$ - Putrescine@ 0.1mM
$S_3$- CPPU @ 10 ppm (1-(2- Chloro-4-Pyridyl)-3-Phenyl Urea)
$S_4$ - Ca $(NO_3)_2$ @ 1%+ Putrescine @ 0.1mM+ CPPU @ 10 ppm
$S_5$ - Control (no chemical spray)

$B_1$ - Two layers of brown paper
$B_2$ - No bagging

## References


1. Abd El-Rhman IE. Physiological studies on cracking phenomena of pomegranates. J Applied Sci Res. 2010;6(6):696-703.
2. Ahmed MS, Singh S. Studies on extension of storage life of ‘Amrapali’ mango. Orissa J Hort. 2000;28:73-76.
3. Akter MM, Islam MT, Akter N, Amin MF, Bari MA, Uddin MS. Pre-harvest fruit bagging enhanced quality and shelf-life of mango (*Mangifera indica* L.) cv. Amrapali. Asian Journal of Agricultural and Horticultural Research. 2020;5(3):45-54.
4. Ali EAM, Sarwy SMA, Hassan HSA. Improving Canino apricot trees productivity by foliar spraying with polyamines. J Applied Sci. Res. 2010;6:1359-1365.
5. Al-Obeed RS, Harhash MM. Effect of bunch bagging colour on “succary” and “khalas” date palm cultivars: Fruit chemical characteristics. Acta Hortic. 2010;882:1213-1217.
6. Arakawa O, Uematsu N, Nakajima H. Effect of bagging on fruit quality in apples. Bulletin of the Faculty of Agriculture, Hirosaki University. 1994;57:25-32.
7. Ataweia AAR, Kh A, Bakry M, Gendiah H, Amin OA. Response of Washington Navel orange trees to some bio and organic nutrients. Egypt. J of App. Sci. 2012;27(7B):433-447.
8. Ayad HS, Yousef ARM, El-Moursi A. Improving fruit and oil quality of picual olive through exogenous application of putrescine and stigmasterol. N.Y. Sci. J. 2011;4:40-45.
9. Babita, Rana VR. Effect of manual fruit thinning and CPPU on the fruit yield and changes in physicochemical composition at harvest and after storage of Allison kiwifruit. International Journal of Bio-resource and Stress Management. 2015;6(6):781-786.
10. Banday FA. Cold storage studies in pear cv. Le Conte. PhD. Dissertation, Punjab Agriculture University,

Ludhiana; c1996.
11. Bangerth F, Dilley DR, Dewey DH. Effect of postharvest calcium treatments on internal breakdown and respiration of apple fruits. Journal of the American Society for Horticultural Science. 1972;97:679-682.
12. Banyal AK, Banyal SK. Forchlorfenuron (CPPU) a promising plant growth regulator augments fruit size, fruit weight, quality and yield of kiwifruit (*Actinidia deliciosa*) cv. Hayward. Int. J Curr. Microbiol. App. Sci. 2020;9(5):2091-2101.
13. Barkule SR, Patel BN, Baghele RD. Effect of 28-Homobrassinolide, CPPU, GA3 and Humic Acid on Quality and Shelf-Life of Sapota (Manilkara achras) CV. Kalipatti Harvested in Winter. Int. J Curr. Microbiol. App. Sci. 2018.Special Issue-6: 962-967.
14. Bhatt A, Mishra NK, Mishra DS, Singh CP. Foliar application of potassium, calicium, zinc and boron enhanced yield, quality and shelf life of mango. Hortflora Research Spectrum. 2012;1(4): 300-305.
15. Biswal A, Rout CK. Effect of cytokinin on fruit crops. Int. J. Curr. Microbiol. App. Sci. 2020;9(11):2896-2903.
16. Bitange NM, Chemining'wa GN, Ambuko J, Owino WO. Yield and Tissue Calcium Concentration of Mango (*Mangifera indica* L.) Fruit as Influenced by Calcium Source and Time of Application. International Journal of Plant & Soil Science. 2019;28(4):1-12.
17. Brahmachari VS, Mandal AK, Kumar R, Rani R, Kumar R. Effect of growth substances on flowering and fruiting characters of Sardar guava (*Psidium gavjava* L.). Hort. J. 1996;9(1):1-7.
18. Burg SP, Burg EA. The interaction between auxin and ethylene and its role in plant growth. Proc. Natl. Acad. Sci. U.S.A. 1966;55(2):262-269.
19. Buronkar MM. Influence of plant growth regulators, polyamine and nutrients on post flowering physiological behaviour in relation to yield and quality in Alphonso mango (Doctoral dissertation, UAS Dharwad). 2005.
20. Bushan PL, Panda C, Dash KA. Effect of pre-harvest chemical treatments and mulching on marketability of mango (*Mangifera indica* L.) cv. Amrapali. Journal of Crop and Weed. 2015;11(1):216-19.
21. Callan NW, Thompson MM, Chaplin MH, Stebbins RL, Westwood MN. Fruit set of Italian prune following fall foliar and spring boron sprays. J Am. Soc. Hort. Sci. 1978;103:253-257.
22. Crisosto CH, Lombard PB, Sugar D, Polito VS. Putrescine influences ovule senescence, fertilization time, and fruit set in 'Comice' pear. J Am. Soc. Hort. Sci. 1988;113:708-712.
23. Debnath S, Mitra SK. Panicle bagging for maturity regulation quality improvement and fruit borer management in litchi (*Litchi chinenesis*). Acta horticulturae. 2008;773:201-209.
24. El-Migeed MMMA, Mostafa EAM, Ashour NE, Hassan HSA, Mohamed DM, Saleh MMS. Effect of potassium and polyamine sprays on fruit set, fruit retention, yield and fruit quality of 'Amhat' date palm. Int. J Agri. Res. 2013;8(2):77-86.
25. El-Wafa M Abou. Effect of Bagging Type on Reducing Pomegranate Fruit Disorders and Quality Improvement. Egypt. J. Hort. 2014;41(2):263-278.
26. Fakir HI, Abed Al-Hussain RM. Effect of spraying whey and mineral nutrition in growth and yield per plant of tomato (*Lycopersicon esculentum* Mill). Tikrit J. 2009;9(2):248-258.
27. Fallahi E, Colt WM, Baird CR, Fallahi B, Chun IJ. Influence of nitrogen and bagging on fruit quality and mineral concentrations of 'BC-2 Fuji' Apple. Hort Technology. 2001;11(3):462-465.
28. Flaishman MA, Shargal A, Stern RA. The synthetic cytokinin CPPU increases fruit size and yield of spadona and costia pear. J Hortic. Sci. Biotechnol. 2001;76:145-149.
29. Fry SC. Primary cell wall metabolism: tracking the carriers of wall polymers in living cells. New Phytol. 2004;161:641-675.
30. Gattass HR, Essa AA, Hend A Marzouk, Safaa El-Nawam M. Effect of application of some growth regulators and $CaCl_2$ on fruit drop, yield and fruit quality of Keitt mango trees. Assiut J Agric. Sci. 2018;49(1):79-95.
31. Gethe AS, Hiray SA, Pujari CV, Patil RV, Lalge PM. Effect of pre-harvest bagging on fruit yield, physiological disorders, pest and diseases in pomegranate. Journal of Entomology and Zoology Studies. 2021;9(1):1543-154.
32. Gill PS, Nav S, Jawandha SK. Post-harvest handling of mango, Review of Punjab Agricultural University. 2005;4:150-160.
33. Glasson WB. The ethylene factor. In the biochemistry of fruits and their products. Academic press London and New York. 1970;1:475-517.
34. Goutam M, Dhaliwal HS, Mahajan BVC. Effect of pre-harvest calcium sprays on post-harvest life of winter guava (*Psidium guajava* L.). J Food Sci. Technol. 2010;47(5):501-506.
35. Greene DW. CPPU influences fruit quality and fruit abscission of McIntosh apples. Hort. Sci. 2001;36(7):1292-1295.
36. Gustafson PG. Growth studies of fruits. Plant Pathology. 1926;1:265-72.
37. Haldankar PM, Parulekar YR, Kireeti A, Kad MS, Shinde SM, Lawande KE. Studies on influence of bagging of fruits at marble stage on quality of mango cv. Alphonso. Journal of Plant Studies. 2015;4(2):12-20.
38. Harhash MM, Al-Obeed RS. Effect of bunch bagging color on yield and fruit quality of date palm. American-Eurasian Journal of Agriculture and Environmental Science. 2010;7:312-319.
39. Hasan MA, Bhattacharjee S, Debnath U. Fruit quality and microclimate variation inside the bunch cover of Dwarf Cavendish banana (Musa AAA). Orissa J Hortic. 2001;29:46-50.
40. Hayat I, Masud T, Rathore HA. Effect of Coating and Wrapping Material on the Shelf Life of Apple (Malus domestica) cv. Borakh. Internet J. Food Safety. 2003;5(5):24-34.
41. Hofman PJ, Smith LG, Joyce DC, Johnson GI, Meiburg GF. Bagging of mango (*Mangifera indica* cv. 'Keitt') fruit influences fruit quality and mineral composition. Postharvest Biol. Technol. 1997;12:83-91.
42. Hongxia W, Wang SB, Shi SY, Ma WH, Zhou YG, Zhan RL. Effects of bagging on fruit quality in Zill mango. Journal of Fruit Science. 2009;26:644-648.
43. Hossain MJ, Hossain MM, Rabbani MG, Hafiz MMH, Islam MZ. Effects of preharvest fruit bagging on postharvest quality and shelf life of mango cv. Amrapali.

J. Bangladesh Agricultural University. 2020;18(1):61-67.
44. Hussein AA, Abd El-Rahman AG, Ahmed RB. Effectiveness of fruit bagging on yield and fruit quality of pomegranate (*Punica granatum*, L.) Annals of Agricultural Science, Moshtohor. 1994;32(2):949-957.
45. Islam MT, Rahman MS, Shamsuzzoha M, Chowdhury AKMMB, Alom R. Influence of pre-harvest bagging on fruit quality of Mango (*Mangifera indica* L.) cv. Mishribhog. International Journal of Biosciences. 2017;11(3):59-68.
46. Islam MT, Shamsuzzoha M, Rahman MS, Bari MA, Akter MM, Khatun A. Effect of bagging time on fruit quality and shelf life of mango (*Mangifera indica* L.) Cv. Langra in Bangladesh. Int. J Agric. Environ. Biores. 2019;4:279-289.
47. Jakhar MS, Pathak S. Enhancing quality of mango (*Mangifera indica*L.) fruits cv. Amrapli with pre-harvest foliar spray and fruit bagging. Annals of Agri-Bio Research. 2014;19(3):488-491.
48. Jiang YM, Chen F. A study on polyamine change and browning of fruit during cold storage of litchi. Postharvest Biol. Technol. 1995;5:245-250.
49. Johns GG, Scott KJ. Delayed harvesting of bananas with ‘sealed’ covers on bunches. 2. Effect on fruit yield and quality. Australian Journal of Experimental Agriculture. 1989;29:727-733.
50. Jyothi K, Ravindra Kumar, Suparna Sinha, Abha Kumara, Preethi Kumari. Impact of chemicals on fruit set and yield contributing characteristics of mango cv. Langra. Journal of Pharmocognosy and phytochemistry. 2018;7(4):1057-1059.
51. Kano Y. Effect of GA and CPPU treatments on cell size and type of sugars accumulated in Japanese pear fruit J. Hort. Sci. Biotechnol. 2003;78:331-334.
52. Karar H, Ahmad M, Ullah H, Wajid M, Zubair M, Raza H. Effectiveness of fruit bagging for the control of insect-pests complex and its impact on quality of mango fruits. Journal of Horticultural Science and Technology. 2019;2(2):45-48.
53. Kazemi M. Influence of foliar application of iron, calcium and zinc sulfate on vegetative growth and reproductive characteristics of strawberry cv. ‘pajaro’. Trakia J. Sci. 2014;1:21-26.
54. Khan AS, Singh Z. Influence of pre and postharvest applications of putrescine on ethylene production, storage life and quality of plum (*Prunus salicina* L. cv. ‘Angelino’). Acta. Hort. 2008;768:125-133.
55. Khan MIR, Trivellini A, Fatma M, Masood A, Francini A, Iqbal N. Role of ethylene in responses of plants to nitrogen availability. Frotiers in Plant Science. 2015;5(6):927.
56. Khattab MM, Shaban AEA. Effect of polyamines on pollen germination, fruit set and retention of mango cv. Ewais. Bulletin of Faculty of Agriculture, Cairo University. 2005;56(2):361-372.
57. Kim JG, Takami Y, Mizugami T, Beppu K, Fukuda T. CPPU application on size and quality of hardy kiwifruit. Scientia Horticulturae. 2006;110:219-222.
58. Kireeti A, Haldankar PM, Parulekar YR. Studies on effect of types of bags on mango fruit (Cv. Kesar) at egg stage. International Journal of Chemical Studies. 2018;6(6):01-04.
59. Kireeti A, Haldankar PM, Babu MRV, Parulekar YR. Effect of pre-harvest bagging on mango fruit quality. Res. Environ. Life Sci. rel. 2016;9(11):1366-1369.
60. Kramer GF, Wang CY, Conway WS. Correlation of reduced softening and increased polyamine levels during low oxygen storage of ‘Mclntosh’ apples. J. Amer. Soc. Hort. Sci. 1989;114:942-946.
61. Kulkarni SS, Patil SS, Magar SD. Effect of plant growth regulators on yield and quality of mango (*Mangifera indica* L.) cv. Kesar. Journal of Pharmacognosy and Phytochemistry. 2017;6(5):2309-2313.
62. Kumar B, Raina R, Kumar R. Improvement in fruit set, retention, weight and yield of apple cv. Royal delicious through foliar application of plant growth regulators. J Krishi Vigyan. 2013;2(1):30-32.
63. Kumar DS, Reddy YN, Har DS. Effect of foliar spray of chemicals on flowering and fruiting of shoots emerging after pruning on mango (*Mangifera Indica* L) cv. Baneshan, South Indian Horticulture. 2003;51:7-11.
64. Kumar MR, Reddy YN, Srihari D. Effect of calcium and plant growth regulators on flowering and yield of mango (*Mangifera indica* L.) cv. Baneshan. Journal of Research of Angrau. 2006;34:11-15,
65. Kumari J, Kumar R, Sinha S, Kumari A, Kumari P. Impact of chemicals on fruit set and yield contributing characteristics of mango (*Mangifera indica* L.) cv. Langra. Journal of Pharmacognosy and Phytochemistry. 2018;7(4):1057-1059.
66. Kuo CT, Lee TC, Tsai PL. Effect of field bagging on the quality of bitter gourd (*Momordica charantia* L.) fruit. J Chin. Soc. Hortic. Sci. 1999;45:152-158.
67. Lal JM. Effect of preharvest bagging on Maturity and Physicochemical properties of guava fruits cv. VNR Bihi. M.Sc. Thesis submitted to the G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand; c2019.
68. Lane JH, Eynon L. Determination of reducing sugars by Fehling’s solution with methylene blue indicator. J. Sci. Chem. India. 1965;42(2):31-39.
69. Leopold AC, Kriedemann PE. Plant Growth and Development. 2nd ed. McGraw-Hill Book Company, New York; c1975.
70. Malik AU, Singh Z. Improved fruit retention, yield and fruit quality in mango with exogenous application of polyamines. Scientia Horticulturae. 2006;110:167-174.
71. Marzouk HA, Kassem HA. Improving yield, quality and shelf life of ‘Thomson seedless’ grape vine by pre harvest foliar applications. Sci. Hort. 2011;130:425-430.
72. Maurya VK, Maurya KK, Praveen Kumar Mishra, Mauriya AK. Influence of foliar spray of nutrient on fruiting and yield of aonla (*Emblica officinalis* Gaertn.) cv. NA-6. The bioscan. 2016;10(1):1183-1186.
73. Mirdehghan SH, Khanamani Z, Shamshiri MH. Preharvest foliar application of putrescine on postharvest quality of fresh pistachio nut. Acta Horticulturae. 2013;1012:299-304.
74. Mirdehghan SH, Rahimi S, Esmaeilizadeh M. Improving the postharvest characteristics of table grape by pre harvest application of polyamines. Acta. Hort. 2013;1012:293-298.
75. Mosa WFA, Nagwa A, Abd EL-Megeed, Aly MAM, Paszt LS. The Influence of NAA, GA3 and Calcium Nitrate on Growth, Yield and Fruit Quality of "Le Conte"

Pear Trees. American Journal of Experimental Agriculture. 2015;9(4):1-9.
76. Mukherjee SK, Dutta MN. Physiochemical changes in Indian guavas during fruit development. Current science. 1967;24:674-675.
77. Nagaharshitha D, Khopkar RR, Haldankar PM, Haldavanekar PC, Parulekar YR. Effect of bagging on chemical properties of mango (*Mangifera indica* L.) cv. alphonso. Agrotechnology. 2014;3:124.
78. Nampila R, Chen BS, Chen CC, Yang YS. Effects of GA3 and CPPU on berry size of seedless grapes. Horticulture NCHU. 2010;35(3):53-64.
79. Naser HM, H.Hanan E, Elsheery NI, Kalaji HM. Effect of biofertilizers and putrescine amine on the physiological features and productivity of date palm (*Phoenix Dactylifera*). Trees. 2016;30(4):1149-1161.
80. Nehad MAAG, EL-Gioushy SF, Baiea MHM. Impact of different bagging types on preventing sunburn injury and quality improvement of Keitt mango fruits. Middle East Journal of Agriculture Research. 2017;6(2):484-494.
81. Niederholzer F, Advisor F, Sutter Counties Y. CPPU for harvest delay improved fruit firmness and size and reduction of preharvest drop in *Prunus domestica* L. (French= prune), Kitren Glozer, Plant Sciences Department, U. C. Davis; c2006.
82. Notodimedjo S. Effect of $GA_3$, NAA and CPPU on fruit retention, yield and quality of mango (cv. Arumanis) in East Java. Acta Hort. 2000;509:587-600.
83. Padmavathamma AS, Hulamani NC. Studies on the effect of fruit bagging on size, quality and colour development of pomegranate (*Punica granatum* C.). J Res. ANGRAU. 1996;24:96-99.
84. Panse VG, Sukhatme PV. Statistical Methods for Agricultural Workers.4th Ed. I.C.A.R., New Delhi. 1985, p.58-152.
85. Parkhe PB, Kulkarni SS, Durgude RA, Mali DS. Effect of chemicals on yield and quality of guava (*Psidium guajava* L.) cv. Sardar. Bio Infolet. 2015;12(2B):491-493.
86. Purbey SK, Kumar A. Effect of Pre-Harvest Bagging on Quality and Yield of Litchi (*Litchi Chinensis*, Sonn.) Fruits. The Bio Scan. Special Issue. 2015;7:197-201.
87. Purohit HP, Butani AM, Parmar P, Chitroda RL, Dodiya KD. Response of pre harvest spray of calcium nitrate and gibberellic acid on physical parameters of guava CV. L-49. International Journal of Chemical Studies. 2019;7(4):87-93
88. Purwoko BS, Kesmayanti N, Susanto S, Nasution MZ. Effect of polyamines on quality changes in papaya and mango fruits. Acta Horti. 1998, 464.
89. Raj Kumar M, Reddy YN, Chandrasekhar R, Srihari D. Effect of calcium and plant growth regulators on flowering and yield of mango (*Mangifera indica* L.) cv. Baneshan. Journal of Research ANGRAU. 2006;34(1):21-25.
90. Ranganna S. Carbohydrates. In: Handbook of Analysis and Quality Control for Fruit and Vegetable Products. 2nd Ed., Tata McGraw Hills, New Delhi. 1986, 5-109.
91. Rathore HA, Masud T, Sammi S, Soomro AH. Effect of Storage on Physico-chemical Composition and Sensory Properties on Mango (*Mangifera indica* L.) Variety Dasehari. Pak. J. Nut. 2007;6:143-148.
92. Ren XL, Ma FW, Wang F. Effect of spermidine on ethylene and respiration of plum. Pl. Physio. Comm. 1995;31:400-411.
93. Romero DM, Valero D, Serrano M, Burlo F, Carbonell A, Burgos L. Exogenous polyamines and gibberellic acid effects on peach (*Prunus persica* L.) storability improvement. J Food Sci. 2000;65:288-294.
94. Romero-Gomezcana NR, Saucedo-Veloz C, Sanchez-Garcia P, Rodriguez Alcazar J, Gonzalez-Hernandez V, M. Foliar application of calcium: physiology and fruit quality of 'Haden' mango. Sociedad Mexicana de la Ciencia del Suelo A.C. 2006;24(4):521-527.
95. Said EA. Effect of Sitofex (CPPU) on Anna apple fruit set and some characteristics. Alexandria J Agril. Res. 2002;47(3):85-92.
96. Samra BN, Shalan AM. Studies on thinning, bagging and aluminium silicate spraying on yield and quality of wonderful pomegranate. J Plant Production, Mansoura Univ. 2013;4(2):219-227.
97. Sankar C, Saraladevi D, Parthiban S. Effect of foliar application of micronutrients and sorbitol on fruit quality and leaf nutrient status of mango cv. Alphonso. The Asian Journal of Horticulture. 2013;8(2):714-719.
98. Sasaki K, Utsunomiya N. Studied Effect of Combined Application of CPPU and GA3 on the Growth of 'Irwin' Mango Fruits". Japanese Journal of Tropical Agriculture. 2012;3(2):144-147.
99. Schmülling T. Cytokinin. Academic Press/Elsevier Science. 2004.
100. Shaban AEA, Hany M, Kamel HM, Rashedy AA, Abd El-Migeed MMM, Moawad HM. Effect of putrescine and whey on improving productivity and fruit quality of Ewais mango. Middle East J Agric. Res. 2017;6(4):908-915.
101. Sharma RR, Pal RK, Asrey R, Sagar VR, Dhiman MR, Rana MR. Pre-harvest fruit bagging influences fruit color and quality of apple cv. Delicious. Agricultural Science. 2013;4(9):443-448.
102. Sharma RR, Reddy SVR, Jhalegar MJ. Preharvest fruit bagging: a useful approach for plant protection and improved post-harvest fruit quality. Journal of Horticultural Science and Biotechnology. 2014;89(2):101-113.
103. Signes AJ, Burlo F, Martinez-Sanchez F, Carbonell-Barrachina AA. Effects of Pre-harvest Bagging on Quality of Black Table Grapes. World J Agril. Sci. 2007;3:32-38.
104. Singh G. Effect of calcium nitrate and plant growth regulators on the storage of 'Allahabad Safeda' guava. Indian J Hort. 1988;45:45-50.
105. Singh JN, Singh DK, Chakravarthy D. Effect of urea and NAA on fruit retention and physico chemical composition of mango cv. Langra. Orissa journal of Horticulture. 1994;22:26-30.
106. Singh RP, Tandon DK, Kalra SK. Change in post-harvest quality of mangoes affected by pre-harvest application of calcium salts. Sci Hort.1993;54:211-219.
107. Singh S, Singh AK, Joshi HK, Bagle BG, Dhandar DG. Storability of ber (*Zizyphus mauritiana* Lamk) fruit in semi-arid environment. J Food Sci Technol. 2008;45:65-69.
108. Singh S, Brahmachari V, Jha KK. Effect of calcium and polythene wrapping on storage life of mango. Indian J Horti. 1998;55(3):218-222.

109. Singh V, Pandey G, Sarolia DK, Kaushik RA, Gora JS. influence of pre harvest application of calcium on shelf life and fruit quality of mango (*Mangifera indica* L.) cultivars. Int. J Curr. Microbiol. App. Sci. 2017;6(4):1366-1372.
110. Stern RA, Flaishman MA, Shargal A. Effect of the synthetic cytokinin CPPU on fruit size and yield of ‘Spadona’ pear. Acta Hort. 2002;596:797-800.
111. Thorp TG, Clearwater MJ, Barnett AM, Martin PJ, Blattmann PJ, Currie MB. ‘Hort16A’ fruit beak end softening and shriveling in California. Acta Hortic. 2007;753(1):389-396.
112. Tian QY, Sun P, Zhang WH. Ethylene is involved in nitrate dependent root growth and branching in Arabidopsis thaliana. New Phytol. 2009;184:918-931.
113. Tombesi A, Antognozzi E, Palliotti A. Influence of light exposure on characteristics and storage life of Kiwifruit. N. Z. J. Crop. Hortic. Sci. 1993;21:87-92.
114. Veltman RH, Kho RM, Van Schaik ACR, Sanders MG, Oosterhaven J. Ascorbic acid and tissue browning in pears (*Pyrus communis* L. cvs Rocha and Conference) under controlled atmosphere conditions. Postharvest Biology and Technology. 2000;19(2):129-137.
115. Venu A, Ramdevputra MV. Effect of Polyamines and NAA Application on Quality and Shelf Life of Mango (*Mangifera indica* L.) cv. Kesar. Int. J Curr. Microbiol. App. Sci. 2018;7(5):2906-2911.
116. Vijay Krishna G. Studies on the effect of plant growth regulators and chemicals on flowering, fruit set and yield of mango cv. Banganpalli. M.Sc. (Hort.) *Thesis* submitted to Dr. YSR Horticultural University, Rajendranagar, Hyderabad. 2012.
117. Vijay Krishna G. Studies on the influence of plant bio regulators and chemicals on phenology, yield and quality of mango cv. Banganpalli. Ph.D., *thesis* submitted to SKLTSHU-Mulugu, College of Horticulture, Rajendranagar. 2019, p-30-55.
118. Walid FA, Nagwa A, Abd EL-Megeed, Lidia Sas Paszt. Effect of the foliar application of potassium, calcium, boron and humic acid on vegetative growth, fruit set, leaf mineral, yield and fruit quality of 'Anna' Apple Trees. American Journal of Experimental Agriculture. 2015;8(4):224-234.
119. Wang L, Kun X, Fang-sheng G, Ning X. Effects of bagging on fruit characteristics and quality in tomato fruits through winter. Scientia Agricultura Sinica. 2007;40(2):345-351
120. Watanawan A, Watanawan C, Jarunate J. Bagging Nam Dok Mai. mango during development affects color and fruit quality. Acta Hortic. 2008;787:325-328.
121. Wu HX, Wang SB, Ma XW, Ma WH, Zhan RL, Yao QS. Effect of Bagging on Fruit Quality in Mango. Acta Hort; c2013. p. 992.
122. Xu CX, Chen HB, Huang RY, He YJ. Effects of bagging on fruit growth and quality of carambola. Acta Hortic. 2008;773:195-200.
123. Yadav I, Sharma RK, Goyal RK, Siddiqui S. Effect of pre-harvest spray of calcium on the storage of ber (*Zizyphus mauritiana* L.) cv. Umran. Haryana Journal of Horticultural Sciences. 2009;38(3&4):243-246.
124. Yang WH, Zhu XC, Bu JH, Hu GB, Wang HC, Huang XM. Effects of bagging on fruit development and quality in cross-winter off-season longan. Sci. Hortic. 2009;120:194-200.
125. Zeraatgar H, Davarynejad GH, Moradinezhad F, Abedi B. Effect of salicylic acid and calcium nitrate spraying on qualitative properties and storability of fresh jujube fruit (*Ziziphus jujube* Mill.). Not Bot Horti Agrobo. 2018;46(1):138-147.
126. Zhang C, Tanabe K, Tani H, Nakajima H, Mori M, Sakuno E. Biologically active gibberellins and ABA in fruit of two late-maturing Japanese pear (*Pyrus pyrifolia* Nakai) cultivars with contrasting fruit size. J Am Soc Hort. Sci. 2007;132:452-458.
127. Zhou J, Zhong G, Lin Z, Xu H. The effects of bagging on fresh fruit quality of Canarium album. Journal of Food Agriculture and Environment. 2012;10(1):505-508.