Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2582-2845.8306

ISSN: 2582 – 2845

Ind. J. Pure App. Biosci. (2020) *8*(4), 499-508

Indian Journal of Pure & Applied Biosciences

Peer-Reviewed, Refereed, Open Access Journal

Research Article

Influence of Plant Growth Regulators on Flowering, Fruiting, Yield and Quality of Sapota [*Manilkara zapota* (L.) P. Royen] cv. Cricket Ball

Akshay[1], Devender Chahal[2*], Mandeep Rathee[3] and Dinesh[4]

*[2]Associate Professor, Krishi Vigyan Kendra, Ambala City - 134003, Haryana

[1]M.Sc. Student, Dept. of Horticulture, CCSHAU, Hisar-125004, Haryana

[3]Training Assistant, Krishi Vigyan Kendra, Kaithal - 136027, Haryana

[4]Junior Pedologist, Dept. of Soil Science, CCSHAU, Hisar - 125004, Haryana

*Corresponding Author E-mail: devenderchahal@rediffmail.com

Received: 6.07.2020 | Revised: 13.08.2020 | Accepted: 19.08.2020

ABSTRACT

The present studies were conducted at Students Experimental Orchard of College of Agricultre, Kaul, (Kaithal), CCS Haryana Agricultural University, Hisar (Haryana) during the fruiting season of year 2018-19 on twenty-eight years old sapota [Manilkara zapota (L.) P. Royen] trees to evaluate the effect of plant growth regulators (PGRs) on flowering, fruit set, yield and quality of fruits. The experiment was laid out in Randomized Block Design with seven treatments replicated thrice to study the effect of CCC (cycocel) 400 ppm sprayed at floral bud differentiation (FBD) stage in July followed by the combinations of other two growth regulators viz., GA_3 (100 and 150 ppm) sprayed at 50% flowering stage and NAA (100, 200 and 300 ppm) sprayed at pea stage of fruit development over the control (only water spray). The different treatment combinations of these three PGRs significantly influenced all the vegetative as well as reproductive (including fruit yield and quality) parameters and performed better than the control. Among different combinations, the application of CCC (cycocel 400 ppm) superimposed with spray of GA_3 (150 ppm) and NAA (300 ppm) was found superior and resulted in maximum increase in plant height (5.69%), stem girth (1.91%) and plant spread (8.64% in E-W and 8.68% in N-S direction), along with maximum number of flowers per cluster (12.56), percentage fruit setting (46.74%), percentage fruit retention (21.25%), number of fruits per cluster (3.87), number of fruits per tree (1,316), yield per tree during the first picking (35.20 kg), second picking (55.83 kg), third picking (37.85 kg) and total yield of three pickings (128.88 kg). In addition to these, the maximum fruit length (6.01 cm), diameter (5.42 cm), weight (97.65 g), TSS content (22.3%), total sugar (14.83%), reducing sugar (8.90%) and non-reducing sugar (5.93%), and the minimum days taken to flowering (23 days), fruit setting (34 days), fruit maturity (218 days) and minimum acidity (0.12%) as well as number of seeds per fruit (1.00) were also obtained with the application of above mentioned combination [i.e. CCC 400 ppm fbs (followed by spray of) GA_3 150 ppm fbs NAA 300 ppm], and it was closely followed by the combination of CCC 400 ppm fbs GA_3 100 ppm fbs NAA 300 ppm in most of the vegetative, floral and fruiting parameters and by the combination of CCC 400 ppm fbs GA_3 150 ppm fbs NAA 200 ppm in most of the fruit quality and yield reproductive parameters. Overall, the application of CCC (400 ppm) at FBD stage followed by the combinations of other two PGRs viz., GA_3 (100 and 150 ppm) sprayed at 50% flowering stage and NAA (200 and 300 ppm) sprayed at pea stage of fruit development proved highly effective in enhancing the yield and quality of cv. Cricket Ball of sapota fruit crop.

Keywords: *Manilkara zapota, Cricket Ball, Plant growth regulators (CCC, NAA, GA_3), Growth, Yield, Quality*

INTRODUCTION

Sapota or sapodilla, [*Manilkara zapota* (L.) P. Royen], an evergreen fruit tree, generally known as chiku in India, belongs to family Sapotaceae and is native fruit of tropical America specially the Southern Mexico and Central America. In India, it was first introduced in Thane District of Maharashtra state in village Gholwad (Chadha, 1992) and presently ranked sixth in important commercial fruit crops after mango, banana, citrus, apple and guava. However, the fruits of sapota are highly perishable and under ordinary conditions can only be stored for a brief period of 7-8 days after harvesting. These fruits are good source of digestible sugar which ranges from 12.0 to 18.0 per cent. Further, the base material for chewing gum i.e. Chickle gum is also extracted from the bark of sapota tree which is also used in dental surgery. The fully ripe fruit is tasty and sweet. Normally, it is a dessert fruit eaten as fresh and possesses outstanding qualities. Sauces, canned slices, ice cream and mixed jam are also prepared from the pulp of the fruit. The fruit possesses a distinguishing pleasant flavor, when blended with milk. Chiku halwa is prepared from sapota shreds by mixing in the milk which is a famous Indian sweet. Liquor and alcohol can also be prepared from sapota fruit due to its higher sugar contents (Chundawat, 1998)**.**

India is the leading producer of sapota in the world with an annual production of approximately 12.94 lakh tonnes of fruits from the crop planted on near about 1.07 lakh hectares (ha) of land. Among the states, Maharashtra tops the table with a production of 4.74 lakh tonnes from 73,000 ha. In Haryana, the area under sapota cultivation is near about 1,632 ha with a production of 16,022 tonnes (Rao, & Saxena, 2017). The area is increasing due to the continuous fruiting throughout the year in humid climate and the hardy nature of crop against biotic and abiotic stresses. Therefore, it becomes the most popular fruit crop of coastal region in the states of Gujarat, Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh and Kerala. For proper growth and development, sapota requires warm and humid climate (70.0% relative humidity with an optimum temperature range of 12 to 36^{o}C). Areas having annual rainfall of 125.0 to 250.0 cm are most suitable for its cultivation, so the climatic conditions of coastal regions and foothills areas of Shivalik region are best suited. Alluvial, sandy loam, red laterite and medium black soils with good drainage are perfect for its cultivation. The main harvesting period is from April to June in Northern Indian regions. In Southern regions, harvesting takes place thrice a year i.e. February, June and September-October (Sulladmath, & Reddy, 1985). The fruit setting of July-August is harvested in April-June in the states of Punjab and Haryana, means - it takes over 10 months from floral bud differentiation up to the full maturity of fruits, and gives only one crop per year. Sapota is a climacteric fruit and can be harvested when fruits are still hard.

Sapota bears heavy flush all over the year in Indian subcontinent but all the flowers do not develop into fruits and all the fruits do not reach up to maturity. Wind plays major role in pollination and also affects the dropping of flowers and fruits at various stages *viz*., starting from flowering up to the fruit maturity. Interestingly, about 95.0% sapota floral buds develop into flowers and out of these, only in the 50.0% flowers fruit setting occurs and among these fruit sets, only 10.0% reach up to the maturity, it means the dropping of fruits instantly take place after the fruit setting.

No doubt under the semi-arid condition of Southwestern Haryana, sapota bears large number of flowers but fruit setting and fruit retention is very low which may be due to several reasons, particularly low auxin level in ovary just after the fruit setting or due to unexpected change in low (in the month of December) and high (in the months of May-June) temperature, but in Northeastern Haryana these problems are least and this crop is comparatively performing well.

Cite this article: Akshay, Chahal, D., Rathee, M., & Dinesh (2020). Influence of Plant Growth Regulators on Flowering, Fruiting, Yield and Quality of Sapota [*Manilkara zapota* (L.) P. Royen] cv. Cricket Ball, *Ind. J. Pure App. Biosci*. *8*(4), 499-508. doi: http://dx.doi.org/10.18782/2582-2845.8306

It is well known fact that the growth regulating chemicals regulate all the developmental stages in fruit crops from seed germination to the maturity and ripening of fruits, so the proper dose of these chemicals should be applied at the correct stage of vegetative as well as reproductive phase to have the maximum beneficial effect on the crop. In sapota, the vegetative growth as well as flowering take place almost side by side depending upon the climatic conditions of that particular area, consequently it is important to use growth retardants to check vegetative growth and the growth promoters to inhibit flower and fruit drop at the right stage, so that these help to make major availability of metabolites towards reproductive phase to obtain higher yields and better quality.

During the last two decades, a lot of attention has been given by researchers to enhance the flowering and fruit setting and to stop the flower and fruit drop in various fruit crops by using the plant growth regulators (PGRs). Different concentrations of PGRs like - CCC, synthetic auxin and gibberellin have been reported to increase the flowering, fruit set, fruit size, fruit quality and yields in sapota (Kadam, Garad, Jadhav, Mangave, & Patgaonkar, 2005; Bhujbal, Naik, & Kale, 2013; Garhwal, 2015). Amongst different synthetic auxins, NAA seems to be most useful in terms of fruit setting and fruit retention in sapota (Nambisan, Desai, Kshirsagar, & Kammble, 2007; Chavan, Patil, Phad, & Suryawanshi, 2009). Likewise, CCC was found to enhance the number of flowers and number of fruits per tree (Agarwal, & Dikshit, 2008) and application of GA_3 also proved highly effective with better fruit set, fruit retention, fruit yield and quality of sapota (Patil, Munde, Nainwad, & Mane, 2011). But unfortunately, till date these findings failed to convince the sapota growers to adopt commercially. Therefore, the present research work was proposed to update the knowledge of extension functionaries and to motivate the farmers to adopt foliar application of PGRs to enhance the productivity of sapota crop in Haryana state.

MATERIALS AND METHODS

The experiment was conducted at Students Experimental Orchard of College of Agriculture, Kaul (Kaithal), under CCS HAU, Hisar (Haryana) during the fruiting season of year 2018-19. The experimental site is located in Northeastern Haryana [237 m above mean sea level (amsl) at 29°51'46" N and 76°39'39" E] and has sub-tropical and sub-humid climate which is characterized by hot desiccating winds during summer season and severe cold in winter season. The average annual rainfall is about 700 mm of which around 80.0 per cent is received during July-September. The temperature may rise up to 45^{o}C during summer season and dips up to 5^{o}C during the winter months of December and January. The sapota trees, on which this experiment was conducted were 28 years old of cv. 'Cricket Ball' grafted on Khirni (*Manilkara hexandra* Roxb.) root stock and planted at a distance of 20 x 20 feet (row to row and plant to plant). These trees were uniformly maintained by applying the doses of manures and fertilizers, irrigation schedule and plant protection measures as recommended in "Package of practices for cultivation of fruit crops" by CCSHAU, Hisar during the period of studies. The experiment was laid out in Randomized Block Design replicated thrice with seven treatments. Out of these seven treatments, one was control (only water was sprayed) and in other six treatments first of all CCC (cycocel) 400 ppm was sprayed at the floral bud differentiation (FBD) stage in month of July, and after that GA_3 (100 and 150 ppm) was sprayed at 50% flowering stage and NAA (100, 200 and 300 ppm) was sprayed at pea stage of the fruit development according to the treatment combinations of different doses.

Plant height (m), stem girth (cm) and tree spread (m) in North-South (N-S) and East-West (E-W) direction of each plant were observed twice, firstly just before the FBD stage in month of July and secondly at the time of third picking of fruits. Height was recorded from ground level up to the top of tree with the help of measuring rod. Stem girth (at 45 cm above the ground level) and tree spread (N-S &

E-W) were recorded using a measuring tape, and then the replication wise mean of each treatment was calculated. Per cent increase in plant height, stem girth and tree spread of individual treatment was calculated by using the mathematical formula.

Observations on reproductive parameters were recorded by selecting four healthy shoots of similar length in all the four directions and from each shoot three clusters were selected and tagged. Days taken up to maximum flowering and the number of flowers in these clusters of each shoot were counted and then the days taken up to maximum flowering and number of flowers per cluster in each treatment were calculated and averaged. Number of days taken to fruit setting were recorded from the date of maximum flowering up to the setting of fruits in each cluster of the selected shoots in each tree and then averaged for each treatment. After the fruit setting, total number of fruits in all the selected clusters of four healthy shoots in each tree were counted and then averaged to calculate the number of setting of fruits per shoot. Percentage of fruit setting in each shoot as compared to flowering of that shoot was calculated for each treatment by using the mathematical formula. Further, the percentage of fruit retention per shoot was calculated by dividing the number of fruits retained till harvesting stage with the setting of total fruits at fruiting stage in a shoot and multiplied by 100. The number of days taken up to fruit maturity were recorded from the date of fruit setting up to the maturity of the fruits in each cluster of the selected shoots in each tree and later on the average of such varied dates was calculated for each treatment.

For recording data on yield parameters *viz*., fruit length (cm), diameter (cm) and weight (g), ten fruits in each treatment were randomly selected. The fruit length and diameter was measured with the help of a digital vernier caliper and fruit weight was recorded by weighing the fruits on digital analytical balance and then the average for each treatment was calculated. Data on number of fruits per cluster was recorded by counting the total number of fruits in all the selected clusters of four healthy shoots in each tree and then the average number of fruits per cluster was calculated for each treatment. Similarly, the total number of fruits on each tree was counted before the first picking and then the average number of total fruits per tree was calculated for each treatment. For calculating yield (kg/tree) of the first three pickings, the number of fruits harvested from the selected trees of each treatment during every picking were counted and multiplied by the average fruit weight of that particular treatment, and then divided by two. In similar way, fruits yield (kg/tree) obtained from each treatment was calculated by the multiplication of average number of total fruits per tree with the average fruit weight as observed in that particular treatment. The data on number of seeds per fruit was recorded by counting the total number of seeds obtained from ten randomly selected fruits produced by trees of each treatment in every replication and then the average number of seeds per fruit was calculated.

For taking observations on quality parameters, pulp obtained from the five randomly selected fruits, as produced by trees with the application of each treatment in every replication, was crushed for extracting the juice and latter was filtered through muslin cloth. The total soluble solids (TSS) of fruits was measured by using Hand Refractrometer (0-32°Brix) at room temperature, and expressed in percentage. The acidity (%) was estimated by using the method given in AOAC (1980). Sugars (reducing, non-reducing and total) were estimated by using the methods of Hulme, & Narain (1931).

RESULTS AND DISCUSSION

Vegetative parameters

Data presented in Table 1 reveals that, however, there was already a significant variation in initial plant height (m), stem girth (cm) and spreading (m) of these 28 years old trees as selected in the experiment, indicating the limitations in selection of uniform size trees at this age of plantation, even then, the application of plant growth regulators influenced most of these parameters

significantly when the observations were recorded at the end of this trial. So, the maximum increase in plant height (5.69%), stem girth (1.91%) and plant spread (8.64% in E-W and 8.68% in N-S) was observed with the combination T_6 (CCC 400 ppm fbs GA_3 150 ppm fbs NAA 300 ppm) and it was followed by T_3 (CCC 400 ppm fbs GA_3 100 ppm fbs NAA 300 ppm) in plant height and stem girth, whereas the minimum increase in plant height (2.99%), stem girth (1.30%) and plant spread (7.10% in E-W and 7.22% in N-S) was recorded in T_7 (control). According to Luckwill (1968), GA_3 stimulates the production as well as downward movement of auxin which in turn promotes the transportation of assimilates to apex to be used in production of new leaves and internodes in apple tree. The increased plant spread may be due to the direct effect of NAA on shoot apical meristem through linear growth by causing cell elongation and plasticity of cell wall. While, GA_3 had probably a stimulatory influence on auxin transport rather than auxin synthesis that results in cell elongation or cell enlargement (Sachs, Lang, Bretz, & Roach, 1960). This may be due to effect of GA_3 which induces cell division, cell elongation and cell enlargement, and also helps in synthesis of protein including various enzymes which increases rate of cell growth and photosynthetic capacity. Similar enhancement in growth parameters with the application of PGRs were also reported by Rajput, Singh, & Singh (1977) in guava; Viswanath, Al-Gabry, & Nadaf (1997) in sapota; Yadav, & Chaturvedi (2005) in ber; and Syamal, Bedanga, & Pakkiyanathan (2010) in papaya. The present findings also got support from other findings of Mostafa, Salhy, Akkad, & Amany (2007) in grape-vines; Hifny, Khalifa, Hamdy, & Abd El-Wahed (2017) in Washington Navel orange; and Sahu, Patel, & Panda (2018) in sapota.

Flowering and fruiting parameters

The data presented in Table 2 clearly indicates that the various combinations of these three PGRs, applied as foliar spray at the different stages of reproductive phase in this fruit crop, significantly influenced all the flowering and fruiting parameters as observed in this study and performed better than the control (T_7). The maximum number of flowers per cluster (12.56) and the minimum days taken to flowering (23 days), fruit setting (34 days) and fruit maturity (218 days) were recorded with treatment T_6 (CCC 400 ppm fbs GA_3 150 ppm fbs NAA 300 ppm), which was closely followed by T_3 (CCC 400 ppm fbs GA_3 100 ppm fbs NAA 300 ppm). The minimum number of flowers per cluster (7.83) and the maximum days taken to flowering (32 days), fruit setting (45 days) and fruit maturity (230 days) were observed in the control (T_7).

Table 1: Effect of plant growth regulators on vegetative parameters of sapota cv. Cricket Ball

Treatments	Height (m)		% Increase	Stem girth (cm)		% Increase	Spread (E-W) (m)		% Increase	Spread (N-S) (m)		% Increase
	Initial	Final		Initial	Final		Initial	Final		Initial	Final	
T1 – CCC 400ppm + GA_3 100ppm + NAA 100ppm	7.58	7.85	3.52	101.33	102.73	1.38	10.77	11.60	7.74	10.77	11.61	7.83
T2 – CCC 400ppm + GA_3 100ppm + NAA 200ppm	7.41	7.75	4.63	111.64	113.23	1.43	9.97	10.72	7.52	11.33	12.20	7.65
T3 – CCC 400ppm + GA_3 100ppm + NAA 300ppm	7.92	8.34	5.26	125.36	127.55	1.74	11.17	12.07	8.09	11.50	12.43	8.09
T4 – CCC 400ppm + GA_3 150ppm + NAA 100ppm	7.82	8.11	3.75	112.27	113.77	1.34	11.20	12.13	8.30	10.20	11.06	8.43
T5 – CCC 400ppm + GA_3 150ppm + NAA 200ppm	8.11	8.49	4.72	121.55	123.37	1.50	10.87	11.79	8.46	10.60	11.48	8.33
T6 – CCC 400 ppm + GA_3 150ppm + NAA 300ppm	7.96	8.41	5.69	117.12	119.35	1.91	11.00	11.95	8.64	11.10	12.06	8.68
T7 – Control (only water spray)	7.69	7.92	2.99	106.32	107.71	1.30	10.47	11.21	7.10	10.80	11.58	7.22
C.D. at 5%	0.36	0.37	-	4.90	4.86	-	0.50	0.61	-	0.55	0.43	-
S.E.(m) ±	0.12	0.12	-	1.57	1.56	-	0.16	0.20	-	0.18	0.14	-

Spray of CCC followed by GA_3 and NAA; Where, CCC: Cycocel, GA_3: Gibberellic acid and NAA: Naphthalene acetic acid; ppm = parts per million

Table 2: Effect of plant growth regulators on flowering and fruiting parameters of sapota cv. Cricket Ball

Treatments	Reproductive parameters					
	No. of flowers per cluster	Days to flowering	Days to fruit Setting	Days to maturity	Fruit setting (%)	Fruit retention (%)
T1 – CCC 400ppm + GA_3 100ppm + NAA 100ppm	9.69	30.00	43.00	228.00	37.26	15.49
T2 – CCC 400ppm + GA_3 100ppm + NAA 200ppm	11.39	27.00	40.00	222.00	38.45	17.63
T3 – CCC 400ppm + GA_3 100ppm + NAA 300ppm	12.30	24.00	35.00	220.00	43.90	20.34
T4 – CCC 400ppm + GA_3 150ppm + NAA 100ppm	11.14	29.00	42.00	225.00	37.61	14.38
T5 – CCC 400ppm + GA_3 150ppm + NAA 200ppm	11.67	26.00	37.00	223.00	40.79	19.55
T6 – CCC 400ppm + GA_3 150ppm + NAA 300ppm	12.56	23.00	34.00	218.00	46.74	21.25
T7 – Control (only water spray)	7.83	32.00	45.00	230.00	36.53	11.36
C.D. at 5%	0.23	1.51	2.10	7.15	2.22	0.85
S.E.(m) ±	0.08	0.49	0.68	2.29	0.71	0.27

Spray of CCC followed by GA_3 and NAA; Where, CCC: Cycocel, GA_3: Gibberellic acid and NAA: Naphthalene acetic acid; ppm = parts per million

Early flowering, fruit setting, fruit maturity and increase in the number of flowers per cluster with the application of PGR may be due to the suppressive effect of CCC on vegetative growth which created favorable C/N ratio in terminals for floral bud initiation at the earliest, and the application of NAA further boost up this process and plants remain physiologically more active to build up sufficient food stock for the developing flowers and eventually resulted in increased number of flowers. The application of GA_3 probably caused early floral bud initiation and flowering by decreasing the concentration of Abscisic acid (ABA) in plant shoot as observed by Phengphachanh, Naphrom, Bundithya, & Potapohn (2012) in orchid. The above findings are also in agreement with the results obtained by Kadam et al. (2005), Nagargoje, Kachave, Shinde, & Jadhav (2007), Nambisan et al. (2007), and Bhujbal et al. (2013) in sapota; and Manju, & Rawat (2015) in local malta.

The maximum fruit setting (46.74%) and fruit retention (21.25%) was also recorded in treatment T_6 (CCC 400 ppm fbs GA_3 150 ppm fbs NAA 300 ppm), and it was closely followed by T_3 (CCC 400 ppm fbs GA_3 100 ppm fbs NAA 300 ppm), while the minimum fruit setting (36.53%) and fruit retention (11.36%) were observed in control (T_7). Such results might be due to fact that the developing fruit requires auxin in higher quantity and fruit drop occurs when the level of auxin goes down, so the exogenous application of auxin fulfills the deficiency and checks the fruit drop and ultimately increases the fruit set. Moreover, NAA served as the nutrition of flower ovary and it may be responsible for the translocation and mobilization of stored metabolites or photosynthates from the source to sink. Further, the spray of GA_3 and NAA also improved the internal physiology of developing fruits by the better supply of nutrients, water and other necessary compounds as required for the growth and development of fruits, ultimately resulting in more fruit retention. The favorable effect of the CCC on fruit retention has been reported by Das, & Mahapatra (1975), and that of GA_3 and NAA by Pharis, & King (1985) in this crop. The above findings are in close conformity with the results obtained by Kadam et al. (2005), Nagargoje et al. (2007), Nambisan et al. (2007), Agarwal, & Dikshit (2008), Chavan et al. (2009) and Bhujbal et al. (2013) in this fruit crop.

Fruit quality parameters

The data presented in Table 3 clearly indicates that the maximum fruit length (6.01 cm), fruit diameter (5.42 cm) and fruit weight (97.65 g), and the highest TSS content (22.30%), total sugar (14.83%), reducing sugar (8.90%), non-reducing sugar (5.93%), and the minimum acidity (0.12%) and number of seeds per fruit (1.00) were obtained in treatment T_6 (CCC 400

ppm fbs GA_3 150 ppm fbs NAA 300 ppm) which was closely followed by T_5 (CCC 400 ppm fbs GA_3 150 ppm fbs NAA 200 ppm) in most of the quality parameters, while the minimum fruit length (5.24 cm), fruit diameter (4.98 cm) and fruit weight (81.33 g), and the lowest TSS content (20.10%), total sugar (12.14%), reducing sugar (7.21%), non-reducing sugar (4.93%), and the maximum acidity (0.19%) and number of seeds per fruit (2.40) were observed in control (T_7). Such improvement in quality parameters of fruits with the application of CCC at FBD stage and superimposed spray of GA_3 and NAA might be due to the translocation of extra metabolites through better partitioning towards the reproductive growth and the more accumulation of assimilates in the fruits resulted in quick conversion of starch into soluble sugar and the hydrolysis polysaccharides into simple sugars during the development of fruit. The reduced number of seeds in fruit may be attributed to the development of parthenocarpic fruit as stimulated by the foliar application of these PGRs. These results are in accordance with the findings of Ray, Samant, Dora, Sahu, & Das (1992), Sudha, Amutha, Muthulaxmi, Baby Rani, Indira, & Mareeswari (2007), Chavan et al. (2009), Agarwal, & Dikshit (2010), Patil et al. (2011), Bhujbal, Naik, & Kale (2012) and Garhwal (2015) in sapota; Pawar, Jagtap, Garad, & Shrisath (2005) in pomegranate; Gupta, & Kaur (2007) in plum; Hazarika, Sangma, Mandal, Nautiyal, & Shukla (2016) in tissue cultured papaya; and Dutta, & Banik (2007) and Singh, Sharma, & Singh (2017) in guava.

Yield parameters

Yield is complex character which depends upon yield contributing factors. It is characterized by the increase in number of fruits per tree and also increase in weight of individual fruit. In the present studies, the spray of PGRs significantly increased the number of fruits as well as fruit weight (Table 3 and 4) and subsequently yield per tree over the control. Data presented in Table 4 reveals that the maximum number of fruits per cluster (3.87), maximum number of fruits per tree (1,316) and the maximum fruit yield during first picking (35.20 kg/tree), second picking (55.83 kg/tree) and third picking (37.85 kg/tree), and ultimately the total yield (128.88 kg/tree) was obtained in treatment T_6 (CCC 400 ppm fbs GA_3 150 ppm fbs NAA 300 ppm) which was significantly higher than all other treatments.

Table 3: Effect of plant growth regulators on fruit quality parameters of sapota cv. Cricket Ball

Treatments	Fruit quality parameters								
	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	TSS (%)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Acidity (%)	No. of seeds/fruit
T1 – CCC 400 ppm + GA_3 100 ppm + NAA 100 ppm	5.42	5.12	88.49	20.4	13.02	7.59	4.93	0.17	1.89
T2 – CCC 400 ppm + GA_3 100 ppm + NAA 200 ppm	5.35	5.08	90.36	20.7	13.23	7.88	5.28	0.17	1.55
T3 – CCC 400 ppm + GA_3 100 ppm + NAA 300 ppm	5.60	5.20	94.78	21.4	13.61	8.26	5.60	0.15	1.67
T4 – CCC 400 ppm + GA_3 150 ppm + NAA 100 ppm	5.76	5.24	93.27	21.1	13.40	8.02	5.43	0.16	1.32
T5 – CCC 400 ppm + GA_3 150 ppm + NAA 200 ppm	5.81	5.32	96.11	22.2	13.72	8.29	5.81	0.13	1.44
T6 – CCC 400 ppm + GA_3 150 ppm + NAA 300 ppm	6.01	5.42	97.65	22.3	14.83	8.90	5.93	0.12	1.00
T7 – Control (only water spray)	5.24	4.98	81.33	20.1	12.14	7.21	4.93	0.19	2.40
C.D. at 5%	0.21	0.25	3.72	0.9	0.68	0.45	0.22	0.01	0.08
S.E.(m) ±	0.07	0.08	1.20	0.3	0.22	0.14	0.07	0.00	0.03

Spray of CCC followed by GA_3 and NAA; Where, CCC: Cycocel, GA_3: Gibberellic acid and NAA: Naphthalene acetic acid; ppm = parts per million

Table 4: Effect of plant growth regulators on yield parameters of sapota cv. Cricket Ball

Treatments	Yield attributes and yield					
	No. of fruits per cluster	No. of fruits per tree	Yield of first three pickings (kg/tree)			Total yield (kg/tree)
			First picking	Second picking	Third picking	
T1 – CCC 400ppm + GA_3 100ppm + NAA 100ppm	1.61	964.14	24.84	39.40	21.41	85.65
T2 – CCC 400ppm + GA_3 100ppm + NAA 200ppm	2.38	981.67	25.74	40.83	22.19	88.76
T3 – CCC 400ppm + GA_3 100ppm + NAA 300ppm	2.74	1064.67	29.12	46.18	25.09	100.39
T4 – CCC 400ppm + GA_3 150ppm + NAA 100ppm	2.19	1044.00	28.37	45.00	24.46	97.83
T5 – CCC 400ppm + GA_3 150ppm + NAA 200ppm	2.76	1194.00	32.73	51.92	30.34	114.99
T6 – CCC 400ppm + GA_3 150ppm + NAA 300ppm	3.87	1316.00	35.20	55.83	37.85	128.88
T7 – Control (only water spray)	0.86	931.97	21.99	34.87	18.96	75.82
C.D. at 5%	0.20	45.70	1.53	1.13	1.44	4.56
S.E.(m) ±	0.06	14.67	0.49	0.36	0.46	1.46

Spray of CCC followed by GA_3 and NAA; Where, CCC: Cycocel, GA_3: Gibberellic acid and NAA: Naphthalene acetic acid; ppm = parts per million

CONCLUSION

From the present investigation, it is concluded that the various combinations of these three plant growth regulators, applied as foliar spray at the particular stages of this fruit crop, significantly influenced all the vegetative as well as reproductive (including fruit yield and quality) parameters and performed better than the control (T_7). Among the different treatment combinations, the application of CCC (cycocel 400 ppm) superimposed by spray of GA_3 (150 ppm) and NAA (300 ppm) was found superior and resulted in maximum increase in plant height (5.69%), stem girth (1.91%) and plant spread in E-W (8.64%) and N-S (8.68%) directions, and the maximum number of flowers per cluster (12.56), percentage of fruit setting (46.74%), percentage of fruit retention (21.25%), number of fruits per cluster (3.87), number of fruits per tree (1,316) and fruit yield during the first picking (35.20 kg/tree), second picking (55.83 kg/tree), third picking (37.85 kg/tree) and the total yield of three pickings (128.88 kg/tree). In addition to these, the maximum fruit length (6.01 cm), diameter (5.42 cm), weight (97.65 g), TSS content (22.30%), total sugar (14.83%), reducing sugar (8.90%) and non-reducing sugar (5.93%), and the minimum days taken to flowering (23 days), fruit setting (34 days), fruit maturity (218 days) and the minimum percentage of acidity (0.12%) as well as number of seeds per fruit (1.00) were also obtained with this combination of growth regulators i.e. T_6 (CCC 400 ppm fbs GA_3 150 ppm fbs NAA 300 ppm), and it was closely followed by the combination T_3 (CCC 400 ppm fbs GA_3 100 ppm fbs NAA 300 ppm) in most of the vegetative, flowering and fruiting parameters and by the combination T_5 (CCC 400 ppm fbs GA_3 150 ppm fbs NAA 200 ppm) in majority of the fruit quality and yield parameters. Overall, the application of CCC (400 ppm) at FBD stage followed by the combinations of other two plant growth regulators *viz*., GA_3 (100 and 150 ppm) sprayed at 50% flowering stage and NAA (200 and 300 ppm) sprayed at pea stage of fruit development was observed to be very effective in enhancing yield and quality of cv. Cricket Ball of sapota fruit crop.

REFERENCES

A.O.A.C. (1980). Official Methods of Analysis, 13th edn. Association of Analytical Chemists, Washington, D.C., USA.

Agarwal, S., & Dikshit, S. N. (2008). Studies on the effect of plant growth regulators on growth and yield of sapota cv. Cricket Ball. *Ind. J. Agric. Res. 42*(3), 207-211.

Agarwal, S., & Dikshit, S. N. (2010). Studies on the effect of plant growth regulators on qualitative characters of sapota cv. Cricket Ball. *Ind. J. Horti. 67*(4), 117-180.

Bhujbal, D. S., Naik, D. M., & Kale, S. A. (2012). Effect of growth regulators on growth and yield of sapota [*Manilkara achras* (Mill.) Fosberg]. *The Asian J. Horti. 7*, 351-353.

Bhujbal, D. S., Naik, D. M., & Kale, S. A. (2013). Studies on effect of growth regulators on flowering, fruiting and quality of sapota. *Ind. J. Agric. Sci. 9*(1), 289-292.

Chadha, K. L. (1992). Strategy for optimization of productivity and utilization of sapota [*Manikara achras* (Mill.) Fosberg]. *Ind. J. Horti. 49*(1), 1-17.

Chavan, S. R., Patil. M. B., Phad, G. N., & Suryawanshi, A. B. (2009). Effect of growth regulators on yield attributes and quality of sapota [*Manilkara achras* (Mill.) Fosberg] cv. Kalipatti. *Asian J. Horti. 4*(1), 176-177.

Chundawat, B. S. (1998). Use of plant growth regulators to increase the yield and quality of sapota. *Agrotech Publishing Academy*, Udaipur.

Das, R. C., & Mahapatra, S. (1975). Effect of growth substances on retention and growth of sapota (*Acharas sapota* L.) fruits. *Plant Sci. 7*, 93-94.

Delvadia, D. V., Chakarwar, V. R., & Makne, V. G. (1994). Effect of growth regulators on flowering and yield of *chiku* during rainy season. *J. Maharashtra Agril. Univ. 19*(3), 346-348.

Dutta, P., & Banik, A. K. (2007). Effect of foliar feeding of nutrients and plant growth regulators on physio-chemical quality of Sardar guava grown in red and lateritic tract of West Bengal. *Acta Hort. 735*, 407-411.

Garhwal, P. C. (2015). Effect of SADH, NAA and GA_3 on growth, yield and quality of sapota [*Manilkara achras* (Mill.) Fosberg] cv. Kalipatti. *M.Sc. thesis* submitted to JAU, Junagadh, India, 76 pp.

Gupta, M., & Kaur, H. (2007). Effect of growth regulators on pre harvest fruit drop in plum (*Prunus salicina* L.) cv. Satluj Purple. *Ind. J. Hort. 64*(3), 278-281.

Hazarika, T. K., Sangma, B. D., Mandal, D., Nautiyal, B. P., & Shukla, A. C. (2016). Effect of plant growth regulators on growth, yield and quality of tissue cultured papaya (*Carica papaya*) cv. Red Lady. *Ind. J. Agric. Sci. 86*(3), 404-408.

Hifny, H. A., Khalifa, S. M., Hamdy A. E., & Abd El-Wahed, A. N. (2017). Effect of GA_3 and NAA on growth, yield and fruit quality of Washington Navel orange. *Egypt J. Hort. 44*(1), 33- 43.

Hulme, A. C., & Narain, R. (1931). The ferricyanide method for determination of reducing sugars- A modification of Hagedorn Jensen Hanes Technique. *Biochem. J. 25*(4), 1051-1056.

Kadam, D. D., Garad, B. V., Jadhav, Y. R., Mangave, K. K., & Patgaonkar, D. R. (2005). Influence of growth regulators on flowering behavior of sapota under semi arid zone of Maharashtra. *J. Soil Crops 15*(1), 111-114.

Luckwill, L. C. (1968). The effect of certain growth regulators on growth and apical dominance of young apple trees. *J. Horti. Sci. 43*(1), 91-101.

Manju, & Rawat, S. S. (2015). Effect of bioregulators on fruit growth and development of local malta (*Citrus sinensis* Osbeck) under valley condition of Garhwal Himalaya. *Inter. J. Plant Ani. Environ. Sci. 5*(2), 105-108.

Mostafa, F. M. A., Salhy, A. M. El., Akkad, M. M. El., & Amany, O. M. (2007). Effect of gibberellic acid and succinic acid on ruby seedless grapevines: I-vegetative growth and pruning wood weight of vines. *Minia J. Agric. Res. Dev. 27*(2), 345-355.

Nagargoje, B. S., Kachave, D. B., Shinde, S. B., & Jadhav, K. M. (2007). Effect of NAA on flower drop, fruit set, fruit drop, fruit retention in sapota cv. Kalipatti. *J. Soil Crops 17*(1), 173-175.

Nambisan, J. V., Desai, U. T., Kshirsagar, D. B., & Kammble, A. B. (2007). Effect of plant growth regulators on yield of sapota cv. Kalipatti. *J. Mahar. Agril. Univ*. *32*(2), 280-281.

Patil, M. B., Munde, G. R., Nainwad, R. V., & Mane, S. S. (2011). Studies on effect of plant growth regulators on physical characters of sapota. *The Asian J. Hort. 6*(1), 98-100.

Pawar, P. S., Jagtap, D.D., Garad, B. V., & Shrisath, H. K. (2005). Effect of plant growth regulators on maturity, yield and fruit weight of pomegranate cv. Mridula. *Adv. in Plant Sci. 18*, 167-170.

Pharis, R. P., & King, R. W. (1985). Gibberellins and reproductive development in seed plants. *Ann. Rev. Plant Physiol. 36*, 517-568.

Phengphachanh, B., Naphrom, D., Bundithya, W., & Potapohn, N. (2012). Effects of day length and gibberellic Acid (GA_3) on flowering and endogenous hormone levels in *Rhynchostylis gigantea* (Lindl.). *Ind. J. Agric. Sci. 4*(4), 217-222.

Rajput, C. B. S., Singh, C. N., & Singh, N. P. (1977). Effect of certain plant growth substances in guava. *Haryana J. Horti. Sci. 6*(3-4), 117-119.

Rao, P. S., & Sexena, M. (2017). Horticultural statistics at a glance: 2017. Department of Agriculture, Cooperation and Farmers Welfare, New Delhi.

Ray, D. P., Samant, P. K. S., Dora, D. K., Sahu, P., & Das, B. K. (1992). Effect of plant growth regulators on fruit set, retention, development and quality of sapota (*A. sapota* L.) cv. Cricket Ball. *Ind. Agriculturist 36*(1), 9-13.

Sachs, R. M., Lang, A., Bretz, C. F., & Roach, J. (1960). Shoot histogenesis: Subapical meristematic activity in a caulescent plant and the action of gibberellic acid and AMO- 1618. *Amer. J. Bot., 47*(4), 260-266.

Sahu, C. K., Patel, M. K., & Panda, C. M. (2018). Effect of pruning and plant growth regulator on physico-chemical quality of sapota (*Manilkara zapota* L.) cv. Cricket Ball. *Inter. J. Curr. Microbiol. Appl. Sci. 7*(9), 1352-1357.

Singh, K., Sharma, M., & Singh, S. K. (2017). Effect of plant growth regulators on fruit yield and quality of guava (*Psidium guajava*) cv. Allahabad Safeda. *J. Pure Appl. Microbiol. 11*(2), 1149-1154.

Sudha, R., Amutha, R., Muthulaxmi, S., Baby Rani, W., Indira, K., & Mareeswari, P. (2007). Influence of pre and post harvest chemical treatments on physical characteristics of sapota (*Achras sapota* L.) var. PKM-1. *Res. J. Agril. Biol. Sci. 3*(5), 450-452.

Sulladmath, U. V., & Reddy, M. A. N. (1985). Sapota. *In: Fruits of India -Tropical and subtropical.* (Ed.) Bose, T. K., Nayaprakash, Calcutta, India, 439-464 pp.

Syamal, M. M., Bedanga, B., & Pakkiyanathan, S. (2010). Influence of growth substances on vegetative growth, flowering and fruit quality of papaya. *Ind. J. Hort. 67*(2), 173-176.

Viswanath, P., Al-Gabry, M., & Nadaf, S. K. (1997). Variability and correlations among growth attributes in sapota. *Annl. Arid Zone 36*(2), 139-141.

Yadav, D. N., & Chaturvedi, O. P. (2005). Influence of GA_3 and trace elements on fruit drop, growth and quality of ber (*Zizyphus mauritiana* L.) cv. Banarasi Karaka. *Farm Sci. J. 14*(1), 27-28.