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IMPACT OF GROWTH RETARDANTS ON GROWTH, FLOWERING, YIELD AND QUALITY OF PAPAYA CV. GJP 1

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ABSTRACT

The investigation entitled impact of growth retardants on dwarfism and flowering of papaya cv. GJP 1 was carried out at Fruit Research Station, Lalbaug, Junagadh Agricultural University, Junagadh during the year 2022-23. The experiment was carried out in Randomized Block Design with three replications and 10 treatments comprised T_1- (Control), T_2- (Ethrel 150 ppm), T_3- (Ethrel 250 ppm), T_4- (Ethrel 350 ppm), T_5- (Cycocel 750 ppm), T_6- (Cycocel 1500 ppm), T_7- (Cycocel 3000 ppm), T_8- (Paclobutrazol 250 ppm), T_9- (Paclobutrazol 500 ppm) and T_{10}- (Paclobutrazol 1000 ppm). The result on the effect of growth retardants indicated that the treatment of cycocel 3000 ppm executed the minimum plant height (142.44 cm), average internodal length (2.87 cm), bearing height (63.97 cm), height of the plant at the time bearing (105.90 cm), leaf stalk length (46.51 cm), days to first flowering (61.83), days to first fruit set (66.61), male: female ratio (plant) (0.89), highest number of leaves (33.74) and from economic point of view, maximum net realization (₹ 587257.41 ha^{-1}) along with benefit cost ratio (2.76) was obtained in cycocel 3000 ppm. Whereas, maximum average fruit length (21.91 cm), average fruit circumference (44.25 cm), average fruit weight (1262.21 g), average pulp weight (1021.35 g), average peel weight (160.65 g), pulp: peel ratio (6.36), TSS (9.10 °Brix), total sugar (9.53 %), reducing sugar (7.99%), non-reducing sugar (1.54%) and minimum average peel weight per cent (12.73%) recorded in treatment ethrel 250 ppm.

Key words : Growth Retardants, Growth, Flowering, Yield and Quality, Papaya.

Introduction

The papaya (*Carica papaya* L.), also referred to as the “wonder fruit of the tropics,” is one of the most significant and delectable fruit crops that are grown in tropical and subtropical regions of the planet that span 32.5 N and S latitudes. The papaya is scientifically known as *Carica papaya* L. It is a member of the 48 species that make up the Caricaceae family, of which only one is edible (Chadha, 1992). Mexico and tropical America are its origins (Heywood *et al*., 2007). It was brought to India in the sixteenth century from Malacca. Papaya is farmed all throughout the world, with India being the world’s top producer. It is grown lushly in Tamil Nadu, Karnataka and Kerala in the southern peninsula of India. In India, there are about 146 thousand hectares of papayas grown, with a total yearly production of 5540 thousand MT and a productivity of 37.94 MT/ha (Anonymous, 2020). Andhra Pradesh is India’s top producer of papaya, followed by Gujarat. Papaya is grown on an estimated 18.189 (‘000) hectares in Gujarat, yielding 1107.880 (‘000) MT of production and 60.90 MT/ha of productivity (Anonymous, 2020).

Papaya is herbaceous, evergreen plants, grows with single and straight trunk. It bears trifoliate leaves with long petioles. The height of papaya ranges up to 2.2 - 2.4 m and it can also withstand in low temperature and up to a height of 1500-2000 m. There are three sex forms of papaya monoecious, dioecious and hermaphrodite (Arrilia *et al.*, 1980). The fruit shape of female plant is short as compared to hermaphrodite plant. The growth of papaya

plant is so unique that after flowering both the processes of leaf and floral initiation and differentiation occurs simultaneously, thus producing fruits continuously all-round the year. Because of its low cost and high nutritious content, papaya is sometimes referred to as the poor man's fruit. It has the following contents: 89.6% moisture, 0.5% protein, 0.1% fat, 9.5% carbs, 0.01% calcium, 0.01% phosphorus, 0.4 % iron, 2020 IU/100 g vitamin A, 0.04 mg nicotinic acid/100 g, 250 mg riboflavin/100 g and 40/ 100 g of calories. Papayas are an excellent source of natural chemicals, in addition to papain, such as pectins, alkaloids, volatile compounds, proteolytic enzymes, and growth inhibitors (Ram, 2005).

Organic compounds known as growth retardants slow down tissue cell division and expansion while physiologically controlling plant height without having an impact on development. In tree fruit crops, the paclobutrazol is becoming more and more common. The majority of plant growth retardants can be employed to stop undesired shoot elongation because they prevent the production of growth-active gibberellins (GAs) (Singh, 2004; Mansuroglu *et al.*, 2009). In ornamental crops, growth retardants are also used to strengthen flower stalks, increase leaf greenness, encourage flowering, and increase resilience to environmental challenges (Kahar, 2008).

Materials and Methods

The experiment entitled under "Impact of growth retardants on growth, flowering, yield and quality of papaya cv. GJP 1" was conducted at Fruit Research Station, Lalbaug, Junagadh Agricultural University, Junagadh during January-2022 to December-2022. The experiment was laid out in Randomized Block Design (RBD) with 10 treatments consist of T_1- (Control), T_2- (Ethrel 150 ppm), T_3- (Ethrel 250 ppm), T_4- (Ethrel 350 ppm), T_5- (Cycocel 750 ppm), T_6- (Cycocel 1500 ppm), T_7- (Cycocel 3000 ppm), T_8- (Paclobutrazol 250 ppm), T_9- (Paclobutrazol 500 ppm) and T_{10}- (Paclobutrazol 1000 ppm) with three replications to study the effect of growth retardants on growth, flowering, yield and quality parameters *viz.*, plant height, average internodal length, bearing height, height of the plant at the time of bearing, leaf stalk length, days to first flowering, days to first fruit set, male: female ratio (plant), number of leaves, length of male flower stalk, length of female flower bud, days to maturity, number of fruits per plant, average fruit length, average fruit circumference, average fruit weight, average pulp weight, average peel weight, pulp: peel ratio, average seed weight, yield, TSS, total sugar, reducing sugar and non-reducing sugar.

Time and Method of Treatment Application of plant growth Retardants

Plant growth retardants solution prepared as per treatment and sprayed on 30th and 45th days after transplanting. The spray was done in morning hours to avoid the transpiration/evaporation losses. The immense care was taken to avoid the contaminated spray of one chemical treatment on other chemical treatment in plants.

Ethrel available in market has 39 per cent active ingredient. To prepare 150, 250 and 350 ppm ethrel solution, respectively 3.8, 6.4 and 8.9 ml ethrel dissolved in 10 liters of water. Cycocel available in market has 50 per cent active ingredient. To prepare 750, 1500 and 3000 ppm cycocel solution, respectively 15, 30 and 60 ml cycocel dissolved in 10 liters of water. Paclobutrazol available in market has 23 per cent active ingredient. To prepare 250, 500 and 1000 ppm paclobutrazol solution, respectively 10.8, 21.73 and 43.47 ml paclobutrazol dissolved in 10 liters of water. The spray was done in such a way that whole plant was spray thoroughly.

Characteristics of GJP 1 variety of Papaya

- GJP 1 (Gujarat Junagadh Papaya 1) variety released from Junagadh Agricultural University, Junagadh in a year 2016-17.
- More number of fruits per tree (36.38)
- Higher fruit yield (84.52 t/ha)
- Less number of seed per fruit
- Medium sized fruit with attractive colour
- Orange yellow colored pulp
- Soft palatable and sweet pulp
- Days to maturity (232 days)
- Fruit weigh (1064 g)
- Fruit length (22.97 cm)
- Fruit girth (44.65 cm)

Observations Recorded

Growth and flowering parameters

Plant height (cm) : The height of plant was measured in centimeters from ground to base of the newly emerged leaf at final harvest with the help of measuring tape then average value was worked out.

Average internodal length (cm) : Average internodal length recorded as the mean distance between adjacent nodes, estimated by dividing the length of the stem by number of nodes within stem. The derived value was noted as per treatment and average value was worked out.

Bearing height (cm) : Height at bearing was recorded as the first fruit set at lowest level from the ground level with the help of measuring tape. The value was noted in observation sheet and average was worked out for further statistical analysis.

Height of the plant at the time of bearing (cm) : Height of the plant at the time of bearing was recorded from ground to base of the newly emerged leaf with the help of measuring tape when first fruit set.

Leaf stalk length (cm) : Leaf stalk length was recorded from the base of the leaf stalk attached to the mother plant to the upper end of the leaf stalk at 7 months after transplanting with the help of measuring tape.

Days to first flowering : The number of days from transplanting"" to emergence of first flower was recorded and then average was worked out.

Days to first fruit set : The period between transplanting to fruit set of first papaya fruit was calculated as number of days to fruit set after transplanting.

Male: Female ratio (plant) : Total number of male and female plants in each treatment was recorded and ratio of male to female plants was calculated.

Number of leaves : The number of leaves per plant was counted time to time from each randomly selected five plants and mean leaves per plant was calculated.

Length of male flower stalk (cm) : The length of male flower stalk was measured from male flower stalk attachment with stem to stalk tip (end) with help of measuring tape and averaged was worked out.

Length of female flower bud (cm) : The length of female flower was recorded from the base of the sessile flower up to tip or end of the flower with the help of measuring tape and averaged value was worked out.

Yield and Yield attributing Parameters

Days to maturity : The period between fruit set to maturity of first papaya fruit was calculated as number of days to fruit maturity.

Number of fruits per plant : The total number of fruits per plant harvested on regular basis was counted from each randomly selected five plants and mean fruits per plant was calculated.

Average fruit length (cm) : Among harvested fruits, five fruits were randomly selected and fruit length was recorded as the length of fruit from apical point to the beak of the fruit with measuring scale and average value was worked out.

Average fruit circumference (cm) : Among harvested fruits, five fruits were randomly selected and middle portion of fruit was selected for circumference of the fruit and measure with the help of measuring tape and average value was worked out.

Average fruit weight (g) : Among harvested fruits, five fruits were randomly selected and weight with the help of weighing balance. The mean value of fruit weight (g) was calculated.

Average pulp weight (g) : From randomly selected five fruits, peel and seeds were removed by sharp knife and remaining pulp was recorded as pulp weight and average value calculated.

Average peel weight (g) : From randomly selected five fruits among harvested fruit removing the peel by sharp knife which was recorded as peel weight and average value calculated.

Average peel weight (%) : Average peel weight per cent was recorded as peel weight divided to total fruit weight and value derived was noted as per treatment and average value was worked out.

Pulp: peel ratio : After separation of pulp and peel from the individual ripe fruit, weight of the pulp and weight of the peel were recorded and pulp: peel ratio was computed by the method of pulp weight was divided by the peel weight.

Average seed weight (g) : Seeds from randomly selected fruits were collected and weight with the help of weighing balance recorded as seed weight of the fruit.

Average yield/plant (kg) : The average yield of fruit per plant harvested on different dates from randomly selected five plants was recorded and summed up.

Yield (t/ha) : The yield of papaya fruits per plant in each treatment converted into yield per hectare based on number of female plants in one hectare area.

Quality parameters

TSS (°Brix) : A digital hand refractometer was used to determine the total soluble solids of the fruit juice. Before usage, the refractometer was calibrated with purified water. The readings were recorded for each sample by putting a drop of juice on the prism and value was recorded and expressed in degree brix (°Brix).

Total sugars (%) : Sample of 0.1 g was mixed and crushed with 10 ml of 2.5 N methanol. Then 0.1 ml aliquot was taken and added 0.9 ml distilled water to make final volume of 1.0 ml. 1.0 ml of phenol 5% and 5.0 ml of 96% H_2SO_4 were added one by one. Then all samples were put in water bath for 10-15 minutes. Spectrophotometer reading was taken at 490 nm wavelength (Rangana, 1986).

Total sugars (%) = Sample O.D. × Standard O.D × Dilution factor × 100 (1)

Reducing sugar (%) : Reducing sugar was estimated by Dinitrosalicylic acid method described by Sadasivam and Manickam (1999). Samples of 0.1 g were extracted with 10 ml of 80 % methanol and crushed well. From the supernatant 0.1 ml aliquot was pipetted out and further 1.9 ml of distilled water was added to make final volume of 2.0 ml. Then 2.0 ml of Dinitrosalicylic acid reagent was added. Then all samples were heated in boiling water-bath for few minutes. After cooling, added 6.0 ml of distilled water. Spectrophotometer reading was taken at 565 nm wavelength. By use of the following formula reducing sugar content was calculated:

$$\text{Reducing sugar}(\%) = \frac{\text{O.D} \times \text{G.F.} \times 100 \times \text{Total volume}}{\text{Sample weight} \times \text{Aliquot taken}} \times 100 \quad (2)$$

Non reducing sugar (%) : Non reducing sugar is calculated by using following formula:

Non-reducing sugars % = Total sugars (%) – Reducing sugars (%) (3)

Economics of Fruit Production

Cost of Cultivation (` ha^{-1}) : In order to evaluate the effectiveness of different treatments and ascertain the most remunerative treatment, the expenses incurred for all the cultivation operations from preparatory tillage to final harvesting including cost of inputs *viz.*, bio pesticides, irrigation, weeding and labour cost *etc.* applied to each treatment were calculated on the basis of prevailing local charges.

Gross Returns (` ha^{-1}) : The gross realization in terms of rupees per hectare was worked out taking into consideration of fruit yields from each treatment and local market prices.

Net Returns (` ha^{-1}) : A net return of each treatment was calculated by deducting the total cost of cultivation from the gross returns.

Benefit: Cost ratio : The benefit cost ratio was worked out by using the following formula:

$$\textbf{BCR} = \frac{\text{Gross realization (` ha}^{-1}\text{)}}{\text{Total cost of cultivation (` ha}^{-1}\text{)}} \quad (4)$$

Data analysis

Collected data was statistically analyzed as per method given by Panse and Sukhatme (1985). All characters were studied for significance by "F" test. Standard error of mean (S. Em.±) and critical difference (CD) were worked out at 5 percent level of significance.

Fig. 1 : General view of experimental site.

Results and Discussion

The data presented in Tables 1, 2, 3, 4, 5 and 6 observed that, growth retardants were produce significant effect on growth, flowering, yield and quality parameters in papaya studied in this experiment and cost of economics.

Plant growth parameters

The investigation of data demonstrated that the application of different treatments of growth retardants had a significant impact on plant growth parameters such as plant height, average internodal length, bearing height, height of the plant at the time of bearing, leaf stalk length and number of leaves.

The minimum plant height (142.44 cm) was noted in plants treated with cycocel 3000 ppm (T_7). It was at par with T_4, T_5, T_6, T_8, T_9 and T_{10} treatments (166.33, 150.89, 142.78, 162.72, 162.22 and 155.00 cm, respectively). The minimum average internodal length (2.87 cm) was noted in plants treated with cycocel 3000 ppm (T_7). It was at par with T_4, T_5, T_6, T_8, T_9 and T_{10} (treatments (3.33, 3.09, 3.05, 3.33, 3.29 and 3.17 cm, respectively). The minimum bearing height (63.97 cm) was noted with application of cycocel 3000 ppm (T_7). It was at par with T_4, T_5, T_6, T_8, T_9 and T_{10} treatments (71.73, 66.07, 65.83, 71.34, 67.87 and 66.57 cm, respectively). The minimum height of the plant at the time of bearing (105.90 cm) was found with application of cycocel 3000 ppm (T_7). It was at par with T_4, T_5, T_6, T_8, T_9 and T_{10} treatments (116.80, 110.67, 107.80, 114.73, 114.19 and 111.07 cm, respectively). The minimum leaf stalk length (46.51 cm) was noted with application of cycocel 3000 ppm (T_7) and found at par with T_5, T_6, T_9 and T_{10} treatments (48.38, 47.95, 50.67 and 49.75 cm, respectively). The maximum number of leaves (33.74) were recorded in cycocel 3000 ppm (T_7) and found at par with T_5 and T_6 treatments (32.53 and 31.96, respectively). The result might be due to the fact that cycocel is a growth retardant which inhibits the plant growth by inhibiting the cyclization of geranylgeranyl pyrophosphate to copyallyl pyrophosphate in the gibberellin

Table 1 : Effect of growth retardants on growth parameters of papaya (*Carica papaya* L.) cv. GJP 1.

Treat. code	Treatments	Plant height (cm)	Average internodal length(cm)	Bearing height (cm)	Height of the plant at the time of bearing (cm)	Leaf stalk length(cm)	Number of leaves
T_1	Control	190.89	3.89	81.07	126.93	60.93	27.93
T_2	Ethrel 150 ppm	173.39	3.53	74.87	122.03	58.78	28.56
T_3	Ethrel 250 ppm	172.86	3.50	73.13	117.77	55.40	29.43
T_4	Ethrel 350 ppm	166.33	3.33	71.73	116.80	54.95	29.47
T_5	Cycocel 750 ppm	150.89	3.09	66.07	110.67	48.38	31.96
T_6	Cycocel 1500 ppm	142.78	3.05	65.83	107.80	47.95	32.53
T_7	Cycocel 3000 ppm	142.44	2.87	63.97	105.90	46.51	33.74
T_8	Paclobutrazol 250 ppm	162.72	3.33	71.34	114.73	53.61	29.83
T_9	Paclobutrazol 500 ppm	162.22	3.29	67.87	114.19	50.67	29.61
T_{10}	Paclobutrazol 1000 ppm	155.00	3.17	66.57	111.07	49.75	30.52
S. Em.±		**8.568**	**0.156**	**2.768**	**3.677**	**2.189**	**1.057**
C.D. at 5%		**25.46**	**0.46**	**8.22**	**10.92**	**6.50**	**3.14**
C. V. %		**9.16**	**8.16**	**6.82**	**5.55**	**7.2**	**6.03**

Table 2 : Effect of growth retardants on flowering parameters of papaya (*Carica papaya* L.) cv. GJP 1.

Treat. code	Treatments	Days to first flowering	Days to first fruit set	Male: Female ratio (plant)	Length of male flower stalk (cm)	Length of female flower bud(cm)
T_1	Control	85.83	92.03	1.45	24.53	3.82
T_2	Ethrel 150 ppm	79.03	84.69	1.38	22.28	4.50
T_3	Ethrel 250 ppm	77.89	83.32	1.37	21.06	4.95
T_4	Ethrel 350 ppm	76.00	81.63	1.31	20.45	4.48
T_5	Cycocel 750 ppm	66.83	71.53	1.08	19.06	4.26
T_6	Cycocel 1500 ppm	64.86	69.60	1.03	18.99	4.33
T_7	Cycocel 3000 ppm	61.83	66.61	0.89	17.82	4.41
T_8	Paclobutrazol 250 ppm	73.26	78.32	1.30	19.68	4.05
T_9	Paclobutrazol 500 ppm	73.01	78.08	1.28	19.94	4.19
T_{10}	Paclobutrazol 1000 ppm	71.00	76.53	1.19	20.65	4.21
S. Em.±		**2.403**	**2.363**	**0.070**	**1.212**	**0.202**
C. D. at 5%		**7.14**	**7.02**	**0.21**	**NS**	**NS**
C. V. %		**5.71**	**5.23**	**9.89**	**10.27**	**8.12**

biosynthesis pathway. This inhibition results in the decrease cell division and elongation arresting the vegetative growth of the plant. These findings are also supported with results of Obadiya *et al*. (2018) in acid lime, Chundawat and Gupta (1974) in phalsa, Guha (1993) in apple, Kumra *et al*. (2018) in strawberry, Kaur *et al*. (2022) grape, Agrawal and Dikshit (2008) in sapota.

Flowering parameters

The data revealed that application of different growth retardants produced significant effect on flowering parameters such as days to first flowering, days to first fruit set, male: female ratio (plant) and non-significant effect on length of male flower stalk and length of female flower bud.

The early flowering appeared in plants which were treated by growth retardants and minimum days to first flowering (61.83) was noted with application of cycocel 3000 ppm (T_7). It was at par with T_5 and T_6 treatments (64.86 and 66.83, respectively). The early fruit set was observed in plants which were treated with growth retardants and minimum days to first fruit set (66.61) was noted with application of cycocel 3000 ppm (T_7) which was at par with T_5 and T_6 treatments (71.53 and 69.60, respectively). The male: female ratio (plant) (0.89)

Table 3. Effect of growth retardants on yield parameters of papaya (*Carica papaya* L.) cv. GJP 1

Treat. No.	Treatments	Days to maturity	Number of fruits per plant	Average fruit length (cm)	Average fruit circumference (cm)	Average fruit weight (g)
T_1	Control	141.27	18.80	17.04	33.89	773.64
T_2	Ethrel 150 ppm	133.62	19.75	20.59	42.31	1139.03
T_3	Ethrel 250 ppm	131.40	19.65	21.91	44.25	1262.21
T_4	Ethrel 350 ppm	131.20	20.12	21.73	40.06	1158.10
T_5	Cycocel 750 ppm	129.32	22.23	18.93	38.30	1024.54
T_6	Cycocel 1500 ppm	124.47	23.46	19.72	39.99	1115.02
T_7	Cycocel 3000 ppm	120.33	25.29	20.43	41.80	1144.83
T_8	Paclobutrazol 250 ppm	130.60	21.09	18.34	35.82	882.39
T_9	Paclobutrazol 500 ppm	130.53	21.22	19.73	36.10	970.38
T_{10}	Paclobutrazol 1000 ppm	129.93	21.90	19.55	39.18	1013.79
S. Em. ±		**3.449**	**1.038**	**0.808**	**1.271**	**27.481**
C. D. at 5 %		**10.25**	**3.08**	**2.40**	**3.78**	**81.65**
C. V. %		**4.59**	**8.43**	**7.07**	**5.62**	**4.54**

Table 4 : Effect of growth retardants on yield parameters of papaya (*Carica papaya* L.) cv. GJP 1.

Treat. code	Treatments	Average pulp weight (g)	Average peel weight (g)	Pulp: Peel ratio	Average seed weight(g)	Average yield/plant (kg)	Yield (t/ha)
T_1	Control	592.33	112.19	5.28	68.78	13.94	43.01
T_2	Ethrel 150 ppm	911.75	156.13	5.84	70.78	24.14	74.50
T_3	Ethrel 250 ppm	1021.35	160.65	6.36	80.18	23.82	73.52
T_4	Ethrel 350 ppm	933.67	151.89	6.15	71.67	22.74	70.19
T_5	Cycocel 750 ppm	810.67	141.74	5.72	71.62	21.84	67.42
T_6	Cycocel 1500 ppm	889.47	153.81	5.78	70.15	23.40	72.23
T_7	Cycocel 3000 ppm	919.10	151.65	6.06	73.95	29.86	92.15
T_8	Paclobutrazol 250 ppm	683.68	124.16	5.51	74.31	18.69	57.67
T_9	Paclobutrazol 500 ppm	758.53	138.53	5.48	73.21	19.62	60.55
T_{10}	Paclobutrazol 1000 ppm	799.33	140.66	5.68	73.13	20.84	64.31
S. Em.±		**23.759**	**4.833**	**0.156**	**2.139**	**1.323**	**4.084**
C. D. at 5 %		**70.59**	**14.36**	**0.46**	**NS**	**3.93**	**12.13**
C. V. %		**4.95**	**5.85**	**4.66**	**5.09**	**10.47**	**10.47**

lowest with application of cycocel 3000 ppm (T_7). It was at par with T_5 and T_6 treatments (1.08 and 1.03, respectively). The early flowering and fruit set in CCC treated plants might be due to CCC promotes the formation and translocation of flowering stimuli as hormones from the leaf to the axils of the leaves and thus produces early flowering compared to other treatments. These early flowering might result in early fruit set. The results are in concurrence with of Hazarika *et al*. (2016) in papaya, Kumar *et al.* (2012) in strawberry, Salomon (1981) in citrus, Brahamchari *et al.* (1996) in guava and Subrata *et al.* (2019) in wood apple. Lowest male: female ratio might be due to unknown action of cycocel in reduction in male flower and increase in female flower. These results are in accordance with Ghose and Sen (1975) in papaya.

Yield parameters

The investigation of data demonstrated that the application of different treatments of growth retardants had a significant impact on fruit yield parameters such as days to maturity, number of fruits per plant, average fruit length, average fruit circumference, average fruit weight, average pulp weight, average peel weight, pulp: peel ratio, yield and non significant effect on seed weight.

The early maturity was noted in plants which were treated with growth retardants and minimum days to maturity (120.33) was noted with application of cycocel

Table 5 : Effect of growth retardants on quality parameters of papaya (*Carica papaya* L.) cv. GJP 1.

Treat. No.	Treatments	TSS(°Brix)	Total sugar(%)	Reducing sugar(%)	Non reducing sugar(%)
T_1	Control	6.69	7. 73	6.82	0.91
T_2	Ethrel 150 ppm	8.40	9.09	7.74	1.35
T_3	Ethrel 250 ppm	9.10	9.53	7.99	1.54
T_4	Ethrel 350 ppm	8.80	9.24	7.80	1.44
T_5	Cycocel 750 ppm	7.57	8.58	7.34	1.25
T_6	Cycocel 1500 ppm	7. 80	8.77	7.54	1.23
T_7	Cycocel 3000 ppm	7.90	8.80	7.63	1.18
T_8	Paclobutrazol 250 ppm	6.92	8.22	7.06	1.16
T_9	Paclobutrazol 500 ppm	7.07	8.28	7.12	1.16
T_{10}	Paclobutrazol 1000 ppm	7.27	8.49	7.26	1.23
S. Em.±		**0.283**	**0.212**	**0.230**	**0.057**
C. D. at 5%		**0.84**	**0.63**	**0.68**	**0.17**
C. V. %		**6.32**	**4.24**	**5.37**	**7.95**

Table 6 : Effect of growth retardants on gross return, net return and benefit cost ratio of papaya cv. GJP 1.

Tr. code	Treatments	Yield (t/ha)	Fixed cost (` ha^{-1})	Variable cost (` ha^{-1})	Total cost of cultivation (` ha^{-1})	Gross return (` ha^{-1})	Net return (` ha^{-1})	Benefit cost ratio
T_1	Control	43.01	325150.00	00.00	325150.00	430100	104950.00	1.32
T_2	Ethrel 150 ppm	74.50	325150.00	3969.12	329119.12	745000	415880.88	2.26
T_3	Ethrel 250 ppm	73.52	325150.00	4290.12	329440.12	735200	405759.88	2.23
T_4	Ethrel 350 ppm	70.19	325150.00	4598.76	329748.76	701900	372151.24	2.13
T_5	Cycocel 750 ppm	67.42	325150.00	4898.15	330048.15	674200	344151.85	2.04
T_6	Cycocel 1500 ppm	72.23	325150.00	6296.29	331446.29	722300	390853.71	2.18
T_7	Cycocel 3000 ppm	92.15	325150.00	9092.59	334242.59	921500	587257.41	2.76
T_8	Paclobutrazol 250 ppm	57.67	325150.00	7113.29	332263.29	576700	244436.71	1.74
T_9	Paclobutrazol 500 ppm	60.55	325150.00	10760.09	335910.09	605500	269589.91	1.80
T_{10}	Paclobutrazol 1000 ppm	64.31	325150.00	18020.23	343170.23	643100	299929.77	1.87

3000 ppm (T_7). It was at par with T_5 (cycocel 750 ppm), T_6 (cycocel 1500 ppm), T_9 (paclobutrazol 500 ppm) and T_{10} (paclobutrazol 1000 ppm) treatments (129.32, 124.47, 130.53 and 129.93, respectively). Likewise, maximum number of fruits per plant (25.29) was noted with application of cycocel 3000 ppm (T_7). Treatment T_7 at par with T_5 (cycocel 750 ppm) and T_6 (cycocel 1500 ppm) treatments (22.23 and 23.46, respectively). The maximum average fruit length (21.91 cm) recorded in ethrel 250 ppm (T_3). It was at par with T_2 (ethrel 150 ppm), T_4 (ethrel 350 ppm), T_6 (cycocel 1500 ppm), T_7 (cycocel 3000 ppm), T_9 (paclobutrazol 500 ppm) and T_{10} (paclobutrazol 1000 ppm) treatments (20.59, 21.73, 19.72, 20.43, 19.73 and 19.55 cm, respectively). The maximum fruit circumference (44.25 cm) was found in ethrel 250 ppm (T_3). It was at par with T_2 (ethrel 150 ppm) and T_7 (cycocel 3000 ppm), treatments (42.31 and 41.80 cm, respectively). Significantly, the maximum average fruit weight (1262.21 g) was found in ethrel 250 ppm (T_3). Significantly, the maximum average pulp weight (1021.35 g) was found in ethrel 250 ppm (T_3).

The minimum average peel weight (112.19 g from 773.64 g fruit) was found in control (T_1). It was at par with T_8 (paclobutrazol 250 ppm) treatment (124.16 g from 882.39 g fruit). The pulp: peel ratio (6.36) of fruit was higher in ethrel 250 ppm (T_3). Treatment T_3 remained at par with T_4 (ethrel 350 ppm) and T_7 (cycocel 3000 ppm) treatments (6.15 and 6.06, respectively). Significantly, the maximum average yield per plant (29.86 kg) was recorded in cycocel 3000 ppm (T_7). Significantly, the maximum (92.15 t/ha) yield ton per hectare was recorded in cycocel 3000 ppm (T_7). The yield increase might be due to inhibition of vegetative growth, resulted to better flowering, fruit set and ultimately higher fruit retention as well as translocation of extra metabolites towards the reproductive growth or sink *i.e.*, fruits. This result in

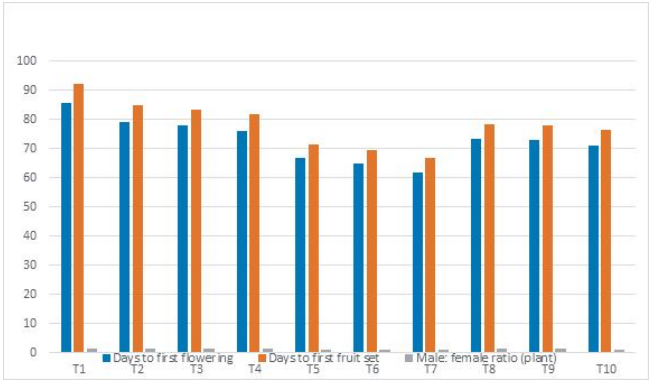

Fig. 2 : Effect of growth retardants on flowering of papaya (*Carica papaya* L.) cv. GJP 1.

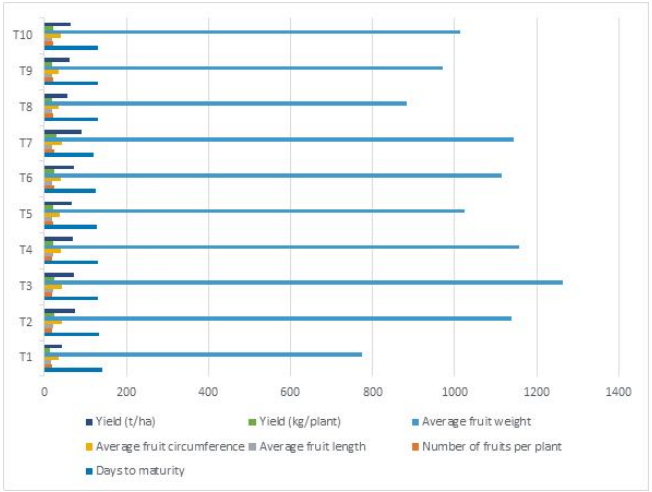

Fig. 3 : Effect of growth retardants on yield of papaya (*Carica papaya* L.) cv. GJP 1.

agreement with the finding Brahamchari *et al.* (1995) in guava, Sarkar *et al*. (1998) in mango, Nath and Baruah (1999) in lemon, Kumar *et al.* (2005) in peach, Agrawal and Dikshit (2008) in sapota, Kumar *et al.* (2012) in strawberry, Patil *et al*. (2016) in mango and Subrata *et al.* (2019) in wood apple.

Quality parameters

The data revealed that application of different growth retardants produced significant effect on quality parameters such as TSS, total sugar, reducing sugar and non-reducing sugar.

The maximum TSS (9.10 °Brix) was found in ethrel 250 ppm (T_3). It was at par with T_2 (ethrel 150 ppm) and T_4 (ethrel 350 ppm), treatments (8.40 and 8.80, °Brix respectively). Similarly, the highest level of total sugar (9.53 %) was found in ethrel 250 ppm (T_3). It was at par with T_2 (ethrel 150 ppm) and T_4 (ethrel 350 ppm), treatments (9.09 and 9.24 %, respectively). The reducing sugar (7.99 %) was higher in ethrel 250 ppm (T_3). It was at par with T_2 (ethrel 150 ppm), T_4 (ethrel 350 ppm), T_5 (cycocel 750 ppm), T_6 (cycocel 1500 ppm) and T_7 (cycocel 3000 ppm), treatments (7.74, 7.80, 7.34, 7.54 and 7.63%, respectively). The maximum non reducing sugar (1.54%) was found in ethrel 250 ppm (T_3). It was at par with T_4 (ethrel 350 ppm) treatment (1.44%). The increase in sugar content in ethrel treated plants might be due to the rapid ripening of fruits and accelerated activities of hydrolytic enzymes, which is associated with high metabolic changes in fruits, leading to the conversion of complex polysaccharides and organic acids into simple sugars through higher respiration and carbon assimilation activity. These results are in line with earlier findings of Syamal *et al*. (2010), Kacha *et al.* (2014) in phalsa and Hazarika *et al*. (2016) in papaya.

Cost of economics

The data revealed that the treatment application of cycocel 3000 ppm (T_7) gave highest net return (` 587257.41 $ha^{-1}$) and BCR (2.76) followed by treatment application of ethrel 150 ppm ($T_2$) gave net return (` 415880.88 ha^{-1}) and BCR (2.26). While lowest net return (` 104950.00 ha^{-1}) and BCR (1.32) noted in control (T_1).

Conclusion

Based on the results obtained from the investigation it can be concluded that the foliar spray of cycocel (3000 ppm *i.e.*, 6 ml/litre of water) at 30th and 45th day after transplanting restricts vegetative growth *viz.*, plant height, bearing height, internodal length, leaf stalk length; moreover, it induces early flowering, fruit set which resulted in early maturity, lower male: female ratio (plant), increases number of leaves and fruits per plant, yield, maximum net realization and BCR. Though, yield attributing characters *viz.*, fruit length, fruit circumference, fruit weight, pulp weight, pulp: peel ratio, biochemical parameters and least peel weight per cent were reported in fruits of treatment of ethrel (250 ppm *i.e.*, 0.64 ml/liter of water) but number of fruits were less.

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