



## Effect of plant growth regulators on growth, yield and quality of tissue cultured papaya (*Carica papaya*) cv. Red Lady

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### ABSTRACT

The present investigation was carried out to find out the response of plant growth regulators on the growth, yield and quality of tissue cultured papaya (*Carica papaya* L.) cv. Red Lady in Mizoram, north-east India. The study indicates that growth yield and quality of the papaya fruits were significantly influenced by plant growth regulators studied. Among treatments, the highest vegetative growth, yield attributing characters and yield were recorded with GA<sub>3</sub> 200 ppm. It also recorded maximum value with respect to different growth parameters, viz. plant height, girth and E-W and N-S spread. Treatment with 200 ppm GA<sub>3</sub> also showed superiority in different yield-attributing characteristics, such as fruit set percentage, number of fruits/plant, fruit length, fruit diameter, fruit circumference, fruit weight, and fruit volume. Quality parameters, such as TSS, acidity, total, reducing and non-reducing sugars of fruits, 400 ppm of ethrel, exhibited significantly maximum value.

**Key words:** Growth, Papaya, Plant growth regulators, Quality, Yield

Papaya (*Carica papaya* L.) is considered as one of the commercial fruit crop of tropical and sub-tropical region because of high remuneration, nutritional and medicinal values. It has emerged from the status of a home garden plant to that of commercial orchards because of the availability of fruits throughout the year, ease of cultivation and the quick returns (Drew *et al.* 1998).

The use of plant growth regulators has assumed an integral part of modern fruit production to improve the quality and production of fruits, and it has resulted in outstanding achievements in a number of fruit crops with regard to improvements in yield and quality (Jain and Dashora 2011). Because of its diverse effects, it is possible to use certain growth regulating chemicals at particular stages of fruit growth and development to exhibit maximum effects. Occasionally, they are needed to be supplemented exogenously for additional stimulus for plants such as papaya, which require quick responses for increased growth, fruit set and yield (Singh and Singh 2009). Considering all of these facts, a pressing need exists to lay out a field experiment to study the influence of plant growth regulators on the growth, yield and physico-chemical characteristics of papaya

cv. Red Lady in Mizoram, north-east India.

### MATERIALS AND METHODS

The present experiment was conducted at the Department of Horticulture, Aromatic and Medicinal Plants at Mizoram University for two consecutive years (2012 to 2014). The land exhibits a moderate slope and a satisfactory drainage system. The experimental field was situated at 23°44'15.1'' N latitudes and 92°39'36.5'' E longitudes. Agro-climatically, the location represents a humid sub-tropical hill zone with an annual rainfall of 208 cm. The elevation of the study site was 779 m above the mean sea level. The soil of the experimental site was sandy loam; available N, P and K were 268.45 kg/ha, 19.40 kg/ha and 120.42 kg/ha, respectively, with 0.65% organic carbon present. The soil was acidic with pH of 4.82.

Healthy and disease and pest infestation free tissue cultured seedlings of the Red lady F<sub>1</sub> hybrid was procured from the Directorate of Horticulture, Government of Mizoram Aizawl, Mizoram, India. The experiment was designed in a randomized block design (RBD) with three replications. The secondary hardened tissue cultured seedlings of the Red Lady cultivar of papaya were planted at a spacing of 1.8 × 1.8 m. There were total of 16 treatment combinations as: T<sub>0</sub>, Control (water spray); T<sub>1</sub>, NAA 100 ppm; T<sub>2</sub>, NAA 150 ppm; T<sub>3</sub>, NAA 200 ppm; T<sub>4</sub>, GA<sub>3</sub> 100 ppm; T<sub>5</sub>, GA<sub>3</sub> 150 ppm; T<sub>6</sub>, GA<sub>3</sub> 200 ppm; T<sub>7</sub>, BA 100 ppm; T<sub>8</sub>, BA 150 ppm; T<sub>9</sub>, BA 200 ppm; T<sub>10</sub>, CCC 500 ppm; T<sub>11</sub>, CCC 750 ppm; T<sub>12</sub>, CCC 1000 ppm; T<sub>13</sub>, ethrel 200 ppm; T<sub>14</sub>, ethrel 300 ppm and T<sub>15</sub>, ethrel 400 ppm.

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The recommended dose of FYM @ 20 tonnes/ha was applied before planting in the respective plots. The recommended dose of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O at 500 g/plant each in the form of urea, single super phosphate and muriate of potash were applied in two split doses, once 2 months after planting and the second at the time of first fruit set in all of the treatments except the control. The plant growth regulators were applied thrice as foliar application 30, 45 and 60 days after planting. Five plants from the middle of each plot were selected randomly and tagged for observation of plant growth characters. The observations on plant growth and yield characters were recorded as standard methods. Percent fruit set was determined as method and formula described by Westwood (1979). Twenty fruits from each treatment were randomly selected to record the data on physico-chemical characters. Fruit size was recorded by measuring the length and breadth using a digital vernier caliper, whereas fruit weight was taken using top pan digital balance. The fruit volume was measured by the water displacement method and expressed in cc. The organoleptic score was determined by a panel of 10 judges in a 10 point scale based on color and softness of the fruits. The TSS was determined with a Zeiss Hand Brix refractometer (0-32 °B). The titratable acidity, total and reducing sugars and ascorbic acid content were determined by the methods suggested in AOAC (1989). The pooled data were analyzed using one way analysis of variance (ANOVA) (Gomez and Gomez 1984), and the means were separated with least significant difference analysis using Duncan's multiple range test (DMRT) at P < 0.05.

## RESULTS AND DISCUSSION

### *Effect of plant growth regulators on the vegetative growth of plants*

The effects of various plant growth regulators on the growth parameters of papaya have been enumerated in Table 1. Plant growth regulators exhibited significantly on the vegetative growth of papaya plants. The maximum plant height (123.16 cm), girth (28.73 cm), E-W and N-S spread (215.63 cm and 223.29 cm, respectively) were recorded with the application of 200 ppm GA<sub>3</sub>, whereas the lowest was recorded in control. This might be due to GA<sub>3</sub> application which increased cell division and cell elongation, thereby increasing the vegetative growth by overcoming genetic dwarfism (Singh and Singh 2009). Vu and Yelenosky (1998) and Syamal *et al.* (2010), also reported an increase in the growth of rough lemon and papaya with the application of GA<sub>3</sub> at various levels. Data contained in Table 1, revealed that the maximum leaves/plant was recorded with the application of 200 ppm BA, which was significantly higher than other treatments. The maximum number of leaves with BA may be due to an increase in cell division caused by cytokinins and also due to the higher supply of assimilates mediated by BA application (Dwivedi *et al.* 1999). Our findings are in close conformity with the findings of Singh and Singh (2009), who also reported an increase in leaf number in strawberry plants with BA application.

Table 1 Plant growth characters as influenced by different plant growth regulators

Treat-ment	Plant height (cm)	Plant girth (cm)	E-W spread (cm)	N-S spread (cm)	Number of functional leaves
T <sub>0</sub>	189.62	28.73	188.02	187.69	37.73
T <sub>1</sub>	214.13	37.78	206.32	213.32	41.73
T <sub>2</sub>	216.01	38.67	206.43	215.29	42.73
T <sub>3</sub>	216.35	38.95	208.71	216.59	43.20
T <sub>4</sub>	220.71	41.33	209.99	218.32	43.40
T <sub>5</sub>	221.35	42.56	212.29	220.95	44.07
T <sub>6</sub>	223.16	43.35	215.63	223.29	44.93
T <sub>7</sub>	210.61	34.65	202.69	207.35	45.40
T <sub>8</sub>	211.99	35.96	203.59	208.59	45.93
T <sub>9</sub>	212.49	37.61	205.69	210.69	47.73
T <sub>10</sub>	203.88	33.59	200.81	201.14	41.20
T <sub>11</sub>	205.69	33.31	201.63	204.97	41.40
T <sub>12</sub>	208.07	33.20	202.21	206.88	41.67
T <sub>13</sub>	196.05	31.39	194.31	193.19	39.53
T <sub>14</sub>	195.99	30.92	193.69	192.36	39.47
T <sub>15</sub>	194.65	30.61	192.95	191.62	38.93
SEM (±)	3.20	2.12	3.17	2.70	0.88
CD (P=0.05)	6.53	4.33	6.47	5.52	1.80

The significant effect of various treatments on flowering and maturity is displayed in Table 2. Plants treated with 1000 ppm CCC required minimum days to flowering (83.67 days) and maturity (164.67 days). The minimum days to flowering in CCC treated plants may be because 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 with other treatments. Our study is in conformity with those of Dwivedi *et al.* (2002) and Kumar *et al.* (2012). The early flowering in CCC-treated plants may be due to its role in producing flowers earlier, which might have resulted in early maturity in the CCC-treated plants.

Similarly, among the different treatments, the maximum number of harvests was recorded with the application of 200 ppm GA<sub>3</sub>, i.e. T<sub>6</sub> (19.64). Our study is in close conformity with the findings of Mohammad *et al.* (1990) and Sharma and Singh (2009), who reported that GA<sub>3</sub> application increased the harvesting period.

### *Effect of plant growth regulators on yield-attributing characteristics*

The maximum fruit set percent was obtained with the application of 200 ppm GA<sub>3</sub> (76.46%), and the lowest was in the control (47.72%) (Table 2). The application of GA<sub>3</sub> resulted in the production of a larger number of flowers with rapid elongation of the peduncle, leading to full development of flower buds exhibiting all functional reproductive parts, which increased fruit set tremendously compared with the control (Voyiatzis and Paroussi 2002). GA also induced the highest number of fruits/plant (72.87). The marked influence of GA on the number of fruits may be attributed to its effects

Table 2 Yield attributing characters of the fruits under different treatments

Treatment	Days to first flowering	Days to maturity	No. of harvests	Percent fruit set	Fruits/plant	Yield/plant (kg)	Yield/ha (tonnes)
T <sub>0</sub>	95.33	177.33	9.44	47.72	48.07	41.53	128.18
T <sub>1</sub>	88.67	170.33	15.72	65.68	64.40	73.03	225.40
T <sub>2</sub>	89.33	169.33	17.35	67.79	66.33	75.54	233.16
T <sub>3</sub>	87.67	168.33	18.00	70.62	68.93	79.63	245.77
T <sub>4</sub>	86.33	167.67	18.34	73.14	69.93	81.81	252.49
T <sub>5</sub>	87.33	167.33	18.37	73.70	70.27	82.70	255.26
T <sub>6</sub>	87.67	166.67	19.64	76.46	72.87	86.23	266.14
T <sub>7</sub>	89.67	173.00	14.13	59.82	56.47	58.94	181.92
T <sub>8</sub>	90.67	172.33	14.37	60.60	58.93	62.87	194.03
T <sub>9</sub>	88.33	171.67	15.47	61.81	63.20	67.85	209.41
T <sub>10</sub>	85.33	166.33	10.22	58.20	55.07	55.92	172.58
T <sub>11</sub>	84.67	165.67	10.43	56.90	53.80	53.50	165.11
T <sub>12</sub>	83.67	164.67	10.61	53.90	52.47	51.15	157.86
T <sub>13</sub>	91.33	173.33	11.57	52.21	50.93	48.68	150.25
T <sub>14</sub>	92.33	174.67	12.88	51.97	49.87	46.66	144.01
T <sub>15</sub>	92.67	175.67	13.52	50.87	49.67	44.93	138.66
SEM (±)	0.90	3.27	0.82	1.24	1.47	1.74	5.37
CD (P=0.05)	1.84	6.68	1.67	2.53	3.00	3.55	10.96

on better pollen germination and fruit set, which favored the production of a larger number of fruits (Sharma and Singh 2009).

#### Effect of plant growth regulators on yield

Observations pertaining to yield/plant and yield/ha were found to be varied significantly (Table 2). From the perusal of data, GA<sub>3</sub> application resulted in the highest yield/plant (86.23 kg) and yield/ha (266.14 tonnes). The increase in yield with gibberellic acid might be due to an increase in flower number, better fruit setting percentage and the production of a higher number of fruits with maximum fruit weight in addition to better vegetative growth. In addition, GA may have affected the auxin metabolism, which may have indirectly aided in fruit enlargement and thus the production of fruits in higher number, which ultimately increases yield/plant and yield/ha (Kappel and MacDonald 2007, Singh and Singh 2006).

#### Effect of plant growth regulators on physical parameters of fruits

The data presented in Table 3 revealed that, GA<sub>3</sub> resulted in the maximum fruit length, (20.43 cm), diameter (14.43 cm), circumference (33.32 cm), fruit weight (1 183.34 g), fruit volume (1 423.34 cc), pulp weight (995.31 g) and peel weight (93.56 g). The exogenous application of GA<sub>3</sub> increased the cell size of the fruit by the proliferation of the sink demand, resulting in enhanced phloem unloading and carbon assimilate metabolism in the fruit and a greater supply of assimilates and photosynthates to the fruits (Zhang *et al.* 2007, Ahmed *et al.* 2012). In addition, GA improved the internal physiology of the developing fruits in terms of a better supply of nutrients and other compounds that are vital for their proper growth and development, which resulted

in improved size and ultimately a greater yield (Pandey 1999).

Application with 400 ppm ethrel resulted in fruits that exhibited highest organoleptic score (8.78/10) compared to other treatments. The highest organoleptic score in ethrel treated plants may be because ethrel, as a ripening hormone, increases the sugar: acid ratio and reduces the fruit pressure, which is an index of fruit hardness or softness. The softening of fruit with ethrel may be explained through its action on cell wall hydrolysis and changes in complex substances to simpler ones, which occurs during ripening under the control of ethylene (Jain and Dashora 2011). Ethrel sharply increased the activity of phenylalanine-ammonialyase in treated fruits, which seems to be a determining factor of color development. Similar increases in organoleptic rating, with ethrel, were also reported in apple plants (Singh *et al.* 2002).

Among the different treatments, the maximum pulp thickness was recorded with 1000 ppm CCC (2.95 cm), and the lowest was in the control (2.18 cm) (Table 3). The increased pulp thickness with CCC might be due to retarded vegetative growths, especially shoot length, and ultimately the accumulation and translocation of metabolites towards the sink (fruit), resulting in thicker pulp (Agrawal and Dikshit 2010). Among the treatments, no significant variation was found with respect to seed number. However, the lowest (377.50) was recorded with gibberellic acid, and the highest was in control (646.80).

#### Effect of plant growth regulators on the chemical parameters of fruits

An inquisition of data presented in Table 4 revealed that application of 400 ppm ethrel resulted in the highest TSS (16.91 %), lowest titrable acidity (0.128 %) and highest total and reducing sugars (10.17 and 7.58%). The increase

Table 3 Physical parameters of the fruits and seeds as affected by plant growth regulators

Treatment	Fruit length (cm)	Fruit diameter (cm)	Fruit circumference (cm)	Fruit weight (g)	Fruit volume (cc)	Organol-ptic score (Out of 10)	Pulp weight (g)	Peel weight (g)	Pulp thickness (cm)	Pulp/peel ratio	Seed weight	Seeds/fruit
T <sub>0</sub>	14.42	9.76	27.24	863.99	1103.99	6.87	715.60	76.81	2.18	9.32	71.58	663.42
T <sub>1</sub>	19.40	13.52	31.48	1134.02	1338.53	8.22	955.10	90.53	2.75	10.58	88.39	467.55
T <sub>2</sub>	19.72	13.73	31.71	1138.74	1342.03	8.30	957.06	91.09	2.76	10.51	90.60	447.13
T <sub>3</sub>	19.82	13.82	32.65	1155.23	1365.03	8.33	966.96	91.75	2.78	10.54	96.52	421.43
T <sub>4</sub>	20.13	14.37	32.85	1170.90	1367.57	8.43	978.10	92.47	2.26	10.58	100.33	396.50
T <sub>5</sub>	20.29	14.40	33.05	1177.00	1396.05	8.50	989.26	93.56	2.33	10.58	94.19	384.40
T <sub>6</sub>	20.43	14.43	33.32	1183.34	1423.34	8.53	995.31	92.12	2.38	10.81	95.91	377.50
T <sub>7</sub>	17.64	12.88	30.18	1043.91	1243.63	7.78	876.25	87.30	2.64	10.04	80.36	523.77
T <sub>8</sub>	17.85	13.24	30.24	1066.70	1278.93	7.88	894.44	89.00	2.69	10.05	83.26	491.93
T <sub>9</sub>	17.90	13.36	30.70	1073.62	1283.97	7.82	904.91	89.91	2.73	10.06	78.79	485.50
T <sub>10</sub>	16.06	10.47	28.43	904.62	1123.95	7.84	742.11	78.16	2.83	9.51	84.35	646.80
T <sub>11</sub>	16.34	10.80	28.81	935.72	1144.06	7.50	758.18	80.35	2.87	9.46	97.18	637.17
T <sub>12</sub>	16.75	10.91	28.91	955.63	1167.93	7.32	781.53	81.41	2.95	9.61	92.69	589.97
T <sub>13</sub>	15.23	11.43	29.43	975.05	1174.53	8.60	813.69	83.44	2.46	9.76	77.91	571.40
T <sub>14</sub>	15.60	12.31	29.73	994.40	1188.45	8.65	831.70	84.52	2.52	9.85	78.18	555.20
T <sub>15</sub>	15.71	12.70	29.80	1015.37	1239.58	8.78	857.88	85.37	2.58	10.06	72.12	533.83
SEM (±)	0.24	0.15	0.23	6.74	14.11	0.11	11.11	2.51	0.02	0.34		9.46
CD (P=0.05)	0.50	0.31	0.48	13.75	28.82	0.23	22.70	5.12	0.05	0.70	NS	19.31

Table 4 Effect of plant growth regulators on chemical parameters of the fruits

Treatment	TSS (°Brix)	Acidity (%)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Ascorbic acid (%)	Sugar: Acid ratio
T <sub>0</sub>	10.50	0.166	8.31	6.44	1.88	65.32	50.24
T <sub>1</sub>	13.61	0.164	8.40	6.62	1.78	80.66	51.11
T <sub>2</sub>	14.07	0.163	8.42	6.65	1.77	80.89	51.66
T <sub>3</sub>	14.72	0.162	8.56	6.71	1.85	81.12	52.73
T <sub>4</sub>	14.99	0.158	8.52	6.72	1.80	81.95	53.84
T <sub>5</sub>	15.03	0.157	8.56	6.73	1.83	82.82	54.66
T <sub>6</sub>	15.74	0.154	8.61	6.86	1.75	83.67	56.04
T <sub>7</sub>	11.13	0.149	8.65	6.46	2.20	78.02	58.06
T <sub>8</sub>	11.71	0.147	8.80	6.47	2.33	78.07	60.02
T <sub>9</sub>	11.73	0.144	8.97	6.49	2.48	78.36	62.46
T <sub>10</sub>	12.71	0.139	8.67	6.55	2.12	67.68	62.35
T <sub>11</sub>	12.81	0.137	8.70	6.57	2.13	68.63	63.35
T <sub>12</sub>	13.62	0.134	8.87	6.60	2.27	69.82	66.39
T <sub>13</sub>	16.67	0.131	9.38	7.29	2.09	72.68	71.59
T <sub>14</sub>	16.73	0.129	9.70	7.50	2.20	73.08	75.39
T <sub>15</sub>	16.91	0.128	10.17	7.58	2.59	73.97	79.49
SEM (±)	0.26	0.001	0.40	0.16		0.92	2.57
CD (P=0.05)	0.53	0.003	0.81	0.32	NS	1.87	5.24

in TSS may be the result of a higher accumulation of metabolites and a quick conversion of starch into soluble sugars during the fruit development in response to growth regulators (Agrawal and Dikshit 2010). The reduction in titratable acidity with ethrel may be due to its action on the fast conversion of organic acids and starch into reducing and non-reducing sugars and their derivatives through higher respiration and carbon assimilation activity during rapid ripening process (Yadav *et al.* 2001). The increase in sugar content in ethrel treated plants may 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 (Yadav *et al.* 2001).

Highest ascorbic acid content was found under different concentrations of gibberellic acid, and the lowest was in the control. The perceptible increase in ascorbic acid with gibberellic acid may be due to catalytic influence of

gibberellic acid on its biosynthesis from its precursor glucose-6-phosphate or the inhibition of its conversion to dehydro-ascorbic acid by ascorbic acid oxidase or both. Similarly, the highest sugar: acid ratio was recorded with the application of 400 ppm ethrel (79.49) and lowest was in control (50.24). Ethrel, a ripening hormone, increases the sugar: acid ratio because of its ability to convert starch to sugars through higher respiration and carbon assimilation activity.

## REFERENCES

- Agrawal S and Dikshit S N. 2010. Studies on the effect of plant growth regulators on qualitative characters of sapota cv. Cricket Ball. *Indian Journal of Horticulture* **67**: 177–80.
- Ahmed W, Tahir F M, Rajwana I A, Raza S A and Asad H U. 2012. Comparative evaluation of plant growth regulators for preventing premature fruit drop and improving fruit quality parameters in ‘Dusehri’ mango. *International Journal of Fruit Science* **12**: 372–89.
- AOAC 1989. *Official Methods of Analysis*, 14<sup>th</sup> edn, pp 22–4. Association of Official Analytical Chemists, Washington DC, USA.
- Chan H T and Tang C S. 1978. The chemistry and biochemistry of papaya. (In) *Tropical Foods*, pp 33–55 Inglett G E and Charolambous G. (Eds).
- Drew P, Beniwal V S and Singh P. 1998. *Papaya*. Corn Publication **59**, pp 66–8.
- Dwivedi M P, Negi K S, Jindal K K and Rana H S. 1999. Influence of photoperiod and bioregulators on vegetative growth of strawberry under controlled conditions. *Advances in Horticulture and Forestry* **7**: 29–34.
- Gomez A A and Gomez K A. 1984. *Statistical Procedures for Agricultural Research*, p 680. John Wiley and Sons, Inc., New York.
- Indian Horticulture Database. 2013. [www.nhb.gov.in/database2013.pdf](http://www.nhb.gov.in/database2013.pdf)
- Jain M C and Dashora L K. 2011. Effect of plant growth regulators on physic-chemical characters and yield of guava cv. Sardar under high density planting system. *Indian Journal of Horticulture* **68**: 259–61.
- Kappel F and MacDonald R. 2007. Early gibberellic acid spray increase fruiting and fruit size of Sweetheart sweet cherry. *Journal of American Pomological Society* **61**: 38–43.
- Kumar R, Sharma N, Jamwal M, Sharma R M, Singh D B and Parmar A M. 2012. Production and economic studies of PBRs treated strawberry (*Fragaria x ananassa* Duch.) cv. Sweet Charlie. *American-Eurasian Journal of Agriculture and Environment Science* **12**: 1 543–7.
- Mohammad A, Hafiz I and Abdul H. 1990. Effect of different concentrations of gibberellic acid on the growth and yield of strawberry. *Sarhad Journal of Agriculture* **61**: 57–9.
- Pandey V. 1999. Effect of NAA and GA spray on fruit retention, growth, yield and quality of ber (*Zizyphus mauritiana* Lamk.) cv. ‘Banarasi’ and ‘Karaka’. *Orissa Journal of Horticulture* **27**: 69–73.
- Samson J A. 1986. *Tropical Fruits*, 2nd ed, pp 256–69. Longman Publishers, New York.
- Sharma R R and Singh R. 2009. Gibberellic acid influences the production of malformed and button berries, and fruit yield and quality in strawberry (*Fragaria x ananassa* Duch.). *Scientia Horticulturae* **119**: 430–3.
- Singh A, Deka, B C, Prakash J, Patel R K and Ojah H. 2010. Problems and prospects of papaya cultivation in northeastern states of India. *Acta Horticulture* **851**: 61–6.
- Singh A and Singh J N. 2009. Effect of biofertilizers and bioregulators on growth, yield and nutrient status of strawberry cv. Sweet Charlie. *Indian Journal of Horticulture* **66**: 220–4.
- Singh A and Singh J N. 2006. Studies on the influence of biofertilizers and bioregulators on flowering, yield and fruit quality of strawberry Cv. Sweet Charlie. *Annals of Agricultural Research* **27**: 261–4.
- Singh A K, Mughal M S and Vachkoo A M. 2002. Effects of ethrel and naphthalene acetic acid on fruit quality and fruit drop of ‘Royal Delicious’ apple. *Indian Journal of Horticulture* **59**: 355–8.
- Syamal M M, Bordoloi B and Pakkiyanathan K. 2010. Influence of plant growth substances on vegetative growth, flowering, fruiting and fruit quality of papaya. *Indian Journal of Horticulture* **67**: 173–6.
- Voyiatzis D C and Paroussi G. 2002. The effect of photoperiod and gibberellic acid on strawberry pollen germination and stamen growth. *Acta Horticulture* **567**: 257–60.
- Vu J C V and Yelenosky G. 1998. Biomass and photosynthesis responses of rough lemon (*Citrus jambhiri* Lush) to growth regulators. *Canadian Journal of Plant Science* **68**: 261–6.
- Westwood M N. 1979. *Temperate Zone Pomology*, p 282. W H Freeman and Co, San Francisco.
- Yadav S J, Bhatia S K, Godara R K and Rana G S. 2001. Effect of growth regulators on the yield and quality of winter season guava cv. L-49. *Haryana Journal of Horticulture Science* **30**: 1–2.
- Zhang C, Tanabe K, Tani H, Nakajima H, Mori M, Itai A and Sakuno E. 2007. Biologically active gibberellins and abscisic acid in fruit of two late-maturing Japanese pear cultivars with contrasting fruit size. *Journal of the American Society for Horticultural Science* **132**:452–8.