J. Hortl. Sci.
Vol. 5 (2): 128-133, 2010

Role of Paclobutrazol and Ethephon in reproductive growth of 'Allahabad Safeda' guava (*Psidium guajava* L.) plants at different spacing

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ABSTRACT

A study on 4-year 'Allahabad Safeda' guava plants was made to assess the influence of Paclobutrazol (PP 333), [(2RS, 3RS)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4 triazol-1-yl) pentan-3-ol], a gibberellin-inhibitor, and Ethephon [(2-chloroethyl) phosphonic acid], a vegetative growth inhibitor and a ripening promoter, on reproductive growth of plants. Treatments in the form of foliar application at 500 and 1000 ppm were applied consecutively during March 2007 and 2008 on plants at 6m x 2m, 6m x 3m, 6m x 4m and 6m x 5m spacing. Maximum flowering and fruit set was recorded in paclobutrazol treated plants in both rainy and winter crops. Ethephon reduced flower bud density (FBD) and fruit set during both the cropping seasons. However, Ethephon treated plants exhibited slightly higher fruit retention. Ethephon advances fruit maturity by upto a week during rainy season and two weeks during winter season. Paclobutrazol treated plants exhibited significantly higher fruit number, fruit yield, yield efficiency, fruiting density compared to Ethephon treated and control plants. Reproductive growth of plants at wider spacing of 6m x 5m and 6m x 4m significantly improved compared to closer spacings of 6m x 2m and 6m x 3m during both cropping seasons. Plants at wider spacing responded better to Paclobutrazol applications with respect to flowering and fruiting.

Key words: Guava, Paclobutrazol, Ethephon, flowering and fruiting

INTRODUCTION

Guava (*Psidium guajava* L.) is an important fruit crop grown throughout the tropics and sub-tropics of the world. It is a very hardy plant, a prolific bearer and highly remunerative fruit crop. It can also be grown satisfactorily under adverse soil and climatic conditions. Productivity of guava can be further enhanced by increasing planting density and by better canopy management. Therefore, high density plantation with a managed canopy, that has balanced vegetative and reproductive growth, is the need of the hour to achieve high productivity per unit area.

In the absence of dwarfing rootstocks in guava, techniques that restrict vegetative growth and promote reproductive growth are important in orchard management. Therefore, apart from pruning and training of roots and shoots, certain growth retardants (alone or in combination) may be exploited. Although a flowering and fruit set under normal planting system is not a problem, there is a wide scope for enhancing the productivity potential of guava plants, particularly under reduced plant spacing. As guava tree responds well to canopy modification with respect to vegetative and reproductive growth (Singh and Chanana, 2005), modification of canopy through pruning and use of certain growth regulators in high density orchards may be required to enhance production efficiency. Some growth regulators like Paclobutrazol and Ethephon may also be very useful in high density planting, as Paclobutrazol helps make the plants dwarf by a retarding effect on vegetative growth of the tree while increasing the number of flower buds. Ethephon acts as a ripening hormone and enhances the ripening process besides having a growth retarding effect. Paclobutrazol @ 500 ppm improved fruit set in winter season crop of guava (Singh and Bal, 2006). Similarly, Jain and Dashora (2007) also recorded highest yield under 500 ppm PBZ treatment.

MATERIAL AND METHODS

The present investigation, relating to reproductive growth of 'Allahabad Safeda' guava (*Psidium guajava* L.) plants at different spacings with Paclobutrazol and Ethephon treatments, was carried out in the New Orchard, Department of Horticulture, Punjab Agricultural University, Ludhiana, during the years 2007-2009. Plants of guava cv.

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'Allahabad Safeda' were planted in March, 2003 at different spacings viz., 6m x 2m, 6m x 3m, 6m x 4m and 6m x 5m, with three replications. Experimental plants were sprayed with Paclobutrazol and Ethephon in both the years @ 500 and 1000ppm, while control plants were sprayed with water, during the month of March. Observations were recorded on fruiting characters, i.e., flower bud density, fruit set, fruit retention, fruit maturity, yield per tree and yield efficiency for both the rainy and winter season crops in May-July and September-December, during both years of study.

For calculation of flower bud density, three tertiary shoots (one meter) of medium vigour each in the upper, middle and lower parts of the tree canopy of every plant were randomly selected and tagged. Number of flowers on each shoot was counted and the average worked out. Fruit set was recorded by counting the number of fruits that had set on tagged shoots after the petal-fall stage and per cent fruit set was calculated. Similarly, fruit retention was calculated by counting the number of fruits left on each tagged shoot 8-10 days before harvest, which was expressed as per cent fruit retention. Fruit maturity was recorded by noting the number of days taken from fruit set to maturity, by counting mature fruits in all the parts of the tree canopy during both the cropping seasons. Maturity was judged on the basis of parameters like colour break, total soluble solids, acidity, firmness and TSS/acid ratio. Fruit yield per tree under each treatment was recorded at harvest and yield efficiency was determined by dividing average fruit load on a tree by canopy volume and was expressed in percentage. Data were analyzed in this Randomized Block Design with split plot.

RESULTS AND DISCUSSION

Flower Bud Density (FBD) : The highest flower bud density for rainy season crop was noted in plants sprayed with PBZ 1000 ppm (35.87 flowers/shoot), followed by 30.74 in plants treated with PBZ 500 ppm. Ethephon 1000 ppm treated plants exhibited the least FBD of 26.9 flowers/meter shoot (Table 1). However, in the winter season guava, FBD was found to be highest (8.53) in Ethephon 500 ppm treated plants and the least (6.32) in untreated plants. Reduction in FBD under higher doses of Ethephon may be due to Ethephon induced leaf shed, causing reduced transfer of the stimulus necessary for induction of flower buds. However, higher FBD in Paclobutrazol treated plants may be due to enhancement of reproductive growth at expense of vegetative growth, reduced by the gibberellin inhibiting effect of Paclobutrazol. Manivannan and Bharthikannan (2005) also found positive a response with respect to number of flowers produced, days to first flower bud appearance, size and yield of fruits, at 1500 ppm Paclobutrazol. In earlier investigations on mango (Winston, 1992, Tongumpai *et al*, 1997, Singh, 2000) and lychee (Manzel and Simpson, 1990), improvement was reported in flowering, with PBZ application. Similarly, Mohammed *et al* (1984) and Castelen and Becerril (1994) reported that Ethephon was appreciably effective in increasing flower bud production in guava.

The mean maximum number of flower buds/1m shoot during rainy season was observed to be 35.93 at 6m x 5m, and 32.31 flowers per meter shoot at 6m x 4m spacing. Plants at closer spacings of 6m x 2m and 6m x 3m produced minimum average number of flower buds/shoot, i.e., 22.44 and 29.4, respectively. During winter, the highest FBD of 14.12 was noted in plants at 6m x 5m spacing, and the least (4.38) in 6m x 3m spaced plants. FBD in the winter season was quite low due to overbearing during the rainy season, i.e., metabolic reserves required for induction of flowering may have got reduced due to heavy flowering in April-May, thereby affecting FBD in August- September in the winter season crop. Reduction in FBD with decrease in plant spacing may be attributed to reduced radiant energy received

Table 1. Effect of Paclobutrazol and Ethephon on flower bud density of 'Allahabad Safeda' guava planted at different spacings

Treatment (ppm)	Spacing (m)									
	Rainy season					Winter season				
	6x2	6x3	6x4	6x5	Mean	6x2	6x3	6x4	6x5	Mean
Paclobutrazol 500	24.18	32.45	38.28	28.06	30.74	4.10	4.75	6.44	17.48	8.19
Paclobutrazol 1000	24.20	34.71	39.92	44.66	35.87	4.58	4.70	8.15	15.39	8.21
Ethephon 500	22.70	27.82	23.87	38.00	28.10	4.88	4.63	8.92	15.68	8.53
Ethephon 1000	21.15	28.85	29.02	28.59	26.90	5.00	3.83	6.69	11.81	6.83
Control	19.96	23.19	30.47	40.36	28.50	5.37	3.97	5.69	10.26	6.32
Mean	22.44	29.40	32.31	35.93	30.02	4.79	4.38	7.18	14.12	7.62
CD *(P=0.05)*	Treatment (A): 6.16					Treatment (A): 1.20				
	Spacing (B): 5.51					Spacing (B) : 1.07				
	Interaction: A x B: 9.64					Interaction: A x B: 1.5				

NS = Non-Significant

Table 2. Effect of Paclobutrazol and Ethephon on fruit set (%) of 'Allahabad Safeda' guava planted at different spacings

Treatment (ppm)	Spacing (m)									
	Rainy season					Winter season				
	6x2	6x3	6x4	6x5	Mean	6x2	6x3	6x4	6x5	Mean
Paclobutrazol 500	45.00	53.48	59.39	48.94	51.70	64.86	66.51	75.19	80.08	71.66
Paclobutrazol 1000	45.00	55.75	61.03	65.78	56.89	65.49	68.26	71.38	78.21	70.84
Ethephon 500	43.78	48.70	44.68	59.11	49.07	64.06	67.00	71.69	76.92	69.92
Ethephon 1000	41.93	49.79	49.96	49.51	47.80	61.20	65.71	69.57	74.41	67.72
Control	40.70	43.99	51.44	61.48	49.40	62.00	68.49	73.07	74.69	69.56
Mean	43.28	50.34	53.3	56.96	50.97	63.52	67.19	72.18	76.86	69.94
CD *(P=0.05)*	Treatment (A): 2.68					Treatment (A): 1.85				
	Spacing (B): 3.00					Spacing (B) : 2.07				
	Interaction: A x B: NS					Interaction: A x B: NS				

NS = Non-Significant

and, also, reduced substrate level with a reduction in shoot growth. The present results are in conformation with those of Lal *et al* (1996), who also found guava trees at closer spacing (2m x2m) producing lower number of flower buds compared to higher spacing (8m x 8m). Similarly, Singh (2003) also recorded an increase in flower bud density with increased plant spacing in guava.

Fruit set: Fruit set in both the seasons improved significantly with PBZ application (Table 2). Average fruit set during the rainy season was found to be maximum when plants were sprayed with PBZ 1000ppm (56.89%) followed by 51.07% in PBZ 500ppm treated plants. The least fruit set (47.8%) was recorded in Ethephon 1000ppm treated plants. In winter season too, PBZ enhanced fruit set. Maximum mean fruit set was found with PBZ 500ppm (71.66%), followed by 70.84% in PBZ 1000ppm treated plants. Minimum average fruit set (67.72%) was noted in Ethephon 1000ppm sprayed plants, followed by 69.56% in untreated plants. Lim and Nualsri (1992) also observed improvement in fruit set of Neck orange with PBZ treatment. Similarly, Singh (2000) reported increase in fruit set in mango with PBZ treatment. Fruit set in plants sprayed with Ethephon, particularly at higher dose, was recorded to be low; this may be due to Ethephon induced leaf shed thus causing an uncongenial microclimate in the tree canopy, which may be responsible for reduced fruit set. On the other hand, PBZ was found to increase fruit set, by channelizing energy available for the vegetative growth to reproductive growth.

During rainy season, the maximum mean fruit set of 56.96% and 53.3% was recorded in the wider spacings of 6m x 5m and 6m x 4m, respectively. The minimum average per cent fruit set of 43.28% was recorded in the close spacing of 6m x 2m. However, in the winter season crop, fruit set was found to be higher than in the rainy season crop due the low number of flowers in winter season. Maximum fruit set (76.86%) was observed in plants at 6m x 5m spacing and the least average fruit set was observed in close spacing of 6m x 2m (63.52%). Low fruit set at close spacing may be due to less spread of trees, and to lower light and air penetration into the canopy. Data in winter season crop are in line with observation of Lal *et al* (1996) who reported lower fruit set in close spacing (2m x 2m) compared to a wider spacing (8m x 8m). However, results of this study are in contradiction to those of Singh (2006), who recorded maximum fruit set at close spacing.

Fruit retention: Growth regulators had significant effect on fruit retention in both rainy and winter season crops of guava. In rainy season guava fruit retention recorded in plants treated with Ethephon 500 and 1000 ppm was 47.66 and 44.36%, respectively and lowest fruit retention (39.62%) was observed in PBZ 500 ppm treated plants (Table 3). In the winter season guava, similar trend of fruit retention was observed. Maximum mean fruit retention was recorded in plants treated with Ethephon 500 ppm (62.56%) and least retention was noted in PBZ 500 ppm (53.73%) and untreated (53.74%) plants. Higher retention in Ethephon treated plants may be due to low FBD and fruit set, resulting in low fruit load on the trees, thereby, enabling plants to hold higher number of fruits owing to higher availability of translocates.

Average per cent fruit retention was not significantly affected by various different spacings during both seasons. However, mean fruit retention was maximum (43.5%) at 6m x 4m, and 59.11% at 6m x 5m spacing. However, the least average per cent fruit retention (41.64 and 55.17%) was observed in 6m x 2m and 6m x 3m spacings during rainy and winter crop seasons, respectively. Retention of winter season fruits in both cultivars was higher than in the rainy season fruits. This may be due to very low fruit count during winter season, there by resulting in higher allocation of nutrients and translocates to fruits on the plants.

Fruit maturity : The treatments had significant effect on fruit maturity in both rainy and winter season crops. Rainy season fruits took relatively less number of days to maturity (Table 4) when sprayed with Ethephon 500 ppm (65.9 days), followed by 66.5 days in Ethephon 1000 ppm treatment. Similarly, in the winter season, fruit maturity was attained earlier, i.e., 105.9 and 106.3 days, with Ethephon 1000 and 500 ppm sprays, respectively. Therefore, Ethephon treatment induced advance maturity by approximately 5-6 days (i.e., earlier) in the rainy season and 10-12 days in the winter season compared to Paclobutrazol treated and control plants. This might be due to Ethephon inducing early ripening, as it is the key plant hormone responsible for fruit ripening. Further, partial leaf shedding due to Ethephon, particularly at the higher dose, may be another factor which enabled light- penetration and a rise in temperature, resulting in early fruit ripening.

Maturity of rainy and winter season crops was not significantly affected by different spacings. However, fruit maturity in widely spaced plants was slightly earlier than in the closer spacing, probably due to higher solar radiation penetration and canopy temperature.

Fruit Yield : Per plant fruit yield was maximum (34.79 kg/ plant) in plants sprayed with PBZ 1000 ppm, followed by 31.55 kg/plant in PBZ 500 ppm treated plants during the rainy season. PBZ 1000 ppm sprayed plants also gave the highest yield of 18.71 kg/plant during the winter season. Lowest per plant yield during rainy season was 23.54 kg and 13.42 kg/plant in winter season (Table 5) in untreated plants. Benjawan *et al* (2006) also reported increase in ‘Kaew’ mango fruit yield with PBZ treatment. Overall yield, primary crop yield and number of primary clusters were seen to be significantly reduced in ‘Chenin Blanc’ grapevine treated with Ethephon upto two weeks after bloom (Szyjewicz and Kliewer, 1983). Yadav *et al* (2001) also recorded minimum yield in ‘Sardar’ guava plants treated with Ethrel compared to control plants. However, Suleman *et al* (2006) found that Ethephon application during May reduced the yield of rainy season guava crop significantly over control, and subsequently increased the yield of winter season crop.

Highest yield was obtained from plants at the widest (6m x 5m) spacing during rainy and winter crop seasons, i.e., 35.3 and 28.65 kg/plant, and, lowest yield of 18.56 and

Table 3. Effect of Paclobutrazol and Ethephon on fruit retention (%) of ‘Allahabad Safeda’ guava planted at different spacings

Treatment (ppm)	Spacing (m)									
	Rainy season					Winter season				
	6x2	6x3	6x4	6x5	Mean	6x2	6x3	6x4	6x5	Mean
Paclobutrazol 500	39.12	38.63	40.37	40.37	39.62	54.23	51.96	52.92	55.80	53.73
Paclobutrazol 1000	38.11	39.52	41.40	41.00	40.01	51.96	51.80	54.70	57.62	54.02
Ethephon 500	46.38	47.40	49.23	47.63	47.66	59.86	62.05	63.01	65.30	62.56
Ethephon 1000	43.21	43.59	45.97	44.65	44.36	58.00	59.25	58.34	63.13	59.68
Control	41.37	41.25	40.54	41.73	41.22	51.81	54.11	55.33	53.71	53.74
Mean	41.64	42.08	43.50	43.08	42.57	55.17	55.83	56.86	59.11	56.74
CD *(P=0.05)*	Treatment (A): 3.10					Treatment (A): 1.34				
	Spacing (B): NS					Spacing (B) : 1.50				
	Interaction: A x B: NS					Interaction: A x B: 1.90				

NS = Non-Significant

Table 4. Effect of Paclobutrazol and Ethephon on fruit maturity (days) of ‘Allahabad Safeda’ guava planted at different spacings

Treatment (ppm)	Spacing (m)									
	Rainy season					Winter season				
	6x2	6x3	6x4	6x5	Mean	6x2	6x3	6x4	6x5	Mean
Paclobutrazol 500	76.5	69.5	72.0	67.8	71.5	115.5	116.8	111.2	119.5	115.8
Paclobutrazol 1000	72.6	72.3	70.5	68.5	71.0	114.8	114.2	110.5	113.2	113.2
Ethephon 500	69.2	65.5	66.5	62.5	65.9	108.6	106.5	105.0	105.2	106.3
Ethephon 1000	68.5	66.8	67.5	63.2	66.5	107.0	106.7	106.5	103.2	105.9
Control	74.2	70.2	71.3	71.2	71.7	114.0	113.8	109.8	110.7	112.1
Mean	72.2	68.9	69.6	66.6	69.3	112.0	111.6	108.6	110.4	110.6
CD *(P=0.05)*	Treatment (A): 0.94					Treatment (A): 0.96				
	Spacing (B): NS					Spacing (B) : NS				
	Interaction: A x B: NS					Interaction: A x B: NS				

NS = Non-Significant

Table 5. Effect of Paclobutrazol and Ethephon on fruit yield (kg/tree) of 'Allahabad Safeda' guava planted at different spacings

Treatment (ppm)	Spacing (m)									
	Rainy season					Winter season				
	6x2	6x3	6x4	6x5	Mean	6x2	6x3	6x4	6x5	Mean
Paclobutrazol 500	20.47	32.06	42.88	30.77	31.55	6.83	8.95	11.93	38.00	16.43
Paclobutrazol 1000	19.30	29.96	48.06	41.85	34.79	8.96	11.71	19.50	34.66	18.71
Ethephon 500	19.73	23.15	23.78	40.67	26.83	12.93	10.40	16.00	33.35	18.17
Ethephon 1000	18.21	24.46	27.80	28.06	24.63	11.68	7.53	16.90	21.00	14.28
Control	15.07	18.05	25.87	35.15	23.54	6.83	13.36	17.25	16.22	13.42
Mean	18.56	25.54	33.68	35.30	28.27	9.45	10.39	16.32	28.65	16.20
CD *(P=0.05)*	Treatment (A): 4.50					Treatment (A): 2.51				
	Spacing (B): 4.64					Spacing (B) : 2.24				
	Interaction: A x B: NS					Interaction: A x B: 3.17				

NS = Non-Significant

Table 6. Effect of Paclobutrazol and Ethephon on yield efficiency (%) of 'Allahabad Safeda' guava planted at different spacings

Treatment (ppm)	Spacing (m)									
	Rainy season					Winter season				
	6x2	6x3	6x4	6x5	Mean	6x2	6x3	6x4	6x5	Mean
Paclobutrazol 500	55.7	84.1	113.6	69.8	80.5	18.6	23.5	31.6	86.2	41.9
Paclobutrazol 1000	50.4	71.6	95.8	94.2	79.6	23.4	28.0	38.9	78.0	42.8
Ethephon 500	47.2	51.1	64.9	100.5	65.4	30.9	23.0	43.6	82.4	44.3
Ethephon 1000	44.6	60.0	72.7	57.5	58.4	28.6	18.5	44.2	43.0	33.9
Control	32.2	32.9	46.8	60.2	43.7	14.6	24.3	31.2	27.8	24.9
Mean	45.4	57.8	77.2	74.8	64.3	23.1	23.5	37.4	60.7	36.8
CD *(P=0.05)*	Treatment (A): 26.52					Treatment (A): 7.10				
	Spacing (B): 23.88					Spacing (B) : 13.92				
	Interaction: A x B: 23.20					Interaction: A x B: 5.85				

NS = Non-Significant

9.45 kg/plant was recorded in plants at the closest spacing of 6m x 2m, respectively. Similar results were reported by Chundawat *et al* (1992), Kalra *et al* (1994), Lal *et al* (2000) and Bal and Dhaliwal (2003) in guava. However, Singh *et al* (2007) also recorded highest yield in guava at 3m x 1.5m spacing from rainy and winter season crops, respectively, and the minimum at 6m x 6m spacing.

Yield efficiency : Yield efficiency of plants under different treatments (Table 6) was influenced significantly during both seasons. During the rainy season, maximum average yield efficiency (80.5%) was noted in PBZ 500 ppm treated plants, followed by 79.6% in PBZ 1000 ppm treatment. Treatments with Ethephon significantly reduced yield efficiency during the rainy season. Lowest efficiency of yield (43.7%) was observed in untreated plants. In the winter season, Ethephon 500 and PBZ 1000 ppm sprays gave the highest yield efficiency of 43.3 and 42.8%, respectively, while, untreated plants exhibited the least yield efficiency of 24.9%, followed by 33.9% in Ethephon 1000 ppm treated plants.

Yield efficiency significantly increased with increase in plant spacing. Maximum average efficiency of yield (77.2%) was recorded in 6m x 4m spacing, followed by 74.8% in 6m x 5m spacing. Least yield efficiency (45.4%) was obtained in plants at 6m x 2m spacing. Similarly, in winter season, maximum mean yield efficiency (60.7%) was noted in 6m x 5m spacing, and the lowest average yield efficiency of 23.1% was recorded in the close spacing of 6m x 2m.

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(MS Received 4 February 2010, Revised 28 June 2010)