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VSSV Prasanna
Uttar Banga Krishi Viswavidyalaya, Coochbehar, Pundibari, West Bengal, India

N Bhowmick
Uttar Banga Krishi Viswavidyalaya, Coochbehar, Pundibari, West Bengal, India

Aditi Chakraborty
Uttar Banga Krishi Viswavidyalaya, Coochbehar, Pundibari, West Bengal, India

MK Debnath
Uttar Banga Krishi Viswavidyalaya, Coochbehar, Pundibari, West Bengal, India

Correspondence
VSSV Prasanna
Uttar Banga Krishi Viswavidyalaya, Coochbehar, Pundibari, West Bengal, India

Effect of paclobutrazol on fruiting characteristics of pineapple [*Ananas comosus* (L.) MERR.] cv. Mauritius

VSSV Prasanna, N Bhowmick, Aditi Chakraborty and MK Debnath

Abstract
Pineapple [*Ananas comosus* (L.) Merr.] is one of the most commercially important fruit crops and belong to the family Bromeliaceae. In pineapple, flowering behaviour is not regularly observed and sometimes even after 18 months of planting only 50% of the flowering may occur and unnecessary delay may be observed. Paclobutrazol (PBZ), plant growth retardant which belong to triazole group, inhibits gibberellin biosynthesis and has been effectively used to induce and manipulate flowering, fruiting in several perennial fruit crops. To evaluate effect of paclobutrazol on flowering characteristics of Pineapple cv. Mauritius, the present experiment was conducted in instructional farm of Pomology and Post-harvest Technology, UBKV, Pundibari during 2016-2018. Paclobutrazol (PBZ) concentrations ranging from 100ppm to 300ppm were used in seven different treatments. Highest yield including crown (42.73t/ha) was recorded in the treatment T_2 compared with the control (36.78t/ha). Highest fruit weight with crown was also recorded in the same treatment.

Keywords: pineapple, paclobutrazol, growth retardant, gibberellin, fruit crops

Introduction
The pineapple Ananas comosus is an herbaceous monocotyledonous perennial tropical plant, of the Bromeliaceae family. It is a xerophytic, succulent, herbaceous, perennial, monocotyledonous plant. It is native to South America and believed to be originated from the area between southern Brazil and Paraguay. Due to presence of crown it is also praised as 'King of Fruits'. In some areas, it is referred as the queen of fruits due to its excellent flavour and taste (Baruwa, 2013) [1]. Flowering in pineapple is an unique and integrated process, of very complex nature and multifactorial control, that has been studied extensively, from eco physiology to biophysics aspects. To overcome the problem of irregular flowering in pineapple, flower forcing in pineapple done with ethylene, ethylene-releasing compounds like ethephon, and CaC_2 or acetylene when the plants are of sufficient size. Paclobutrazol (PBZ), a triazole derivative, has been effectively used to induce and manipulate flowering, fruiting and tree vigour in several perennial fruit crops. It is a triazole plant growth regulator which inhibits gibberellin biosynthesis and regulates flowering (Davis *et al.*, 1988) [3]. Soil application of paclobutrazol has been efficacious in promoting flowering and increasing yield in many fruit crops (Kundan *et al*., 2015) [8].

Materials and Methods
The experimental site was ploughed and levelled. Trenches were made at the specified spacing. Suckers of uniform size of Mauritius pineapple were planted in the trenches at the spacing of 30 cm ×45cm ×90cm in double row planting systems during last week of November 2016. The design used in the experiment was Randomised Block Design (RBD) having 3 replications and 7 treatments. Ten plants from each replication were treated with 0.434ml, 0.868ml and 1.302ml concentration of paclobutrazol for 100ppm, 200ppm and 300ppm concentration of paclobutrazol respectively in one litre solution. For each plant 50 ml solution is applied at the centre of the leaf rosett and the plants were tagged. Treatment details are given below:
Fruit physical characteristics like fruit weight with crown (g) and fruit weight without crown (g) was recorded by weighing individual fruit by a digital balance and the weight (g) was recorded.

Fruit length (cm), crown length (cm) and fruit circumference (cm) were measured with measuring tape and expressed in cm. Pulp weight, peel weight, core weight and crown weight of individual fruit were recorded with digital balance and expressed in (g). Pulp percentage (%), peel percentage (%), core percentage (%) and crown percentage (%) were calculated by dividing the pulp weight (g), peel weight (g), core weight (g) and crown weight (g) with the fruit weight with crown respectively. Yield (t/ha) was calculated by multiplying the individual fruit weight with flowering percentage. Biochemical parameters like TSS content of fruit Juice was estimated using digital refractometer and expressed in (°Brix). The procedure followed for measuring TSS of the fruit was as described by (Ranganna, 2010). Total sugar and reducing sugar of the fruit juice was measured by following the procedure described by (Ranganna, 2010) [10]. and expressed in (%). Titrable acidity of the fruit was measured by following procedure described by (Ruck, 1969) [11].and expressed in (%). Ascorbic acid content of the fruit was measured by following the procedure described by (Ranganna, 2010) [10]. TSS/acid ratio was calculated by dividing TSS with the Titrable acidity. Statistical analysis was performed by using RBD statistical design and CD at 5% level of significance.

Treatment	Treatment Details
T_1	Paclobutrazol @ 100 ppm at 8Months after planting (MAP)
T_2	Paclobutrazol @ 100 ppm at 8MAP+9MAP
T_3	Paclobutrazol @ 200 ppm at 8MAP
T_4	Paclobutrazol @ 200 ppm at 8MAP+9MAP
T_5	Paclobutrazol @ 300 ppm at 8MAP
T_6	Paclobutrazol @ 300 ppm at 8MAP+9MAP
T_7	Control

Results

The data was presented in Table 1 showed that paclobutrazol in different concentrations has significant role for fruit weight without crown. Highest fruit weight without crown was observed in T_2 (865.49g) and lowest fruit weight without crown was seen in control (745.04g). The data was presented in Table 1. Showed that paclobutrazol in different concentrations has significant role for fruit weight with crown. Highest fruit weight with crown was seen in in T_2 (1042.02g) and lowest fruit weight without crown was seen in control (877.12g).The data pertaining to fruit length was presented in the Table 1. Showed that paclobutrazol in different concentrations has no influence on the fruit length. Highest fruit length was observed in the in T_2 (14.53cm) and lowest fruit length was seen in control (13.35cm).

The data pertaining to crown length was presented in the Table 1. Showed that paclobutrazol in different concentrations has no influence on the crown length of the fruit. Highest crown length was observed in the in control (13.43cm) and lowest crown length was seen in T_2 (12.45cm).

The data pertaining to fruit circumference was presented in the Table 1. Showed that paclobutrazol in different concentrations has no influence on the fruit circumference of the fruit. Highest fruit circumference was observed in the in T_2 (29.06cm) and lowest fruit circumference was seen in T_6 (24.60cm).

Table 1: Effect of paclobutrazol on physical parameters of fruit

Treatment	Fruit weight with crown (g)	Fruit weight without crown (g)	Fruit length (cm)	Length of the crown (cm)	Fruit circumference (cm)	Number of eyes (No)	Fruit yield with crown t/ha	Fruit yield without crown t/ha
T_1(PBZ @ 100 ppm at 8MAP)	940.62	781.61	13.44	13.09	26.6	112.14	46.44	38.59
T_2(PBZ @ 100 ppm at 8 &9 MAP)	1043.32	865.49	14.53	12.45	29.06	115.64	51.51	42.73
T_3(PBZ @ 200 ppm at 8MAP)	887.15	746.57	13.63	13.06	26.36	105.32	43.31	36.78
T_4 (PBZ@ 200 ppm at 8 &9MAP)	905.80	748.84	13.39	13.2	26.65	112.46	44.72	36.97
T_5 (PBZ @ 300 ppm at 8MAP)	880.31	746.43	13.35	12.69	26.4	109.2	43.17	36.85
T_6(PBZ @ 300 ppm at 8 &9 MAP)	890.07	749.16	13.39	12.67	24.6	108.42	43.95	36.99
T_7(Control)	877.12	745.04	13.31	13.43	25.5	109.38	43.03	36.56
S.Em(±)	14.16	12.05	0.34	0.36	0.81	1.77	0.72	0.61
C.D, at 5%	44.13	38.9	N.S	N.S	N.S	5.53	2.68	1.92

The data pertaining to number of eyes was presented in the Table 1. Showed that paclobutrazol in different concentrations manifested significant influence on the number of eyes of the fruit. Highest number of eyes were observed in the in T_2 (115.64) and lowest number of eyes were seen in T_3 (105.32). This may be due to the role of PBZ on cell elongation.

The data pertaining to fruit yield with crown was presented in Table 1. Results revealed that paclobutrazol treatments manifested significant influence on fruit yield with crown. Highest fruit yield with crown was seen in T_2 (51.51t/ha) and lowest fruit yield with crown was seen in control (43.03t/ha). The data pertaining to fruit yield without crown was presented in Table 1. Results revealed that paclobutrazol treatments manifested significant influence on fruit yield without crown. Highest fruit yield without crown was seen in T_2 (42.73t/ha) and lowest fruit yield without crown was seen in control (36.56t/ha).

It was evident from Table 2. That paclobutrazol treatments had significant influence on the pulp weight of the fruit. Highest pulp weight of the fruit was observed in T_2 (586.43g) and lowest pulp weight was seen in control (506.01g).

It was clear from Table 2. That paclobutrazol treatments had significant influence on the peel weight of the fruit. Highest peel weight of the fruit was observed in T_2 (197.77g) and lowest peel weight was seen inT_3 (143.34g). Table 2. Depicts that paclobutrazol treatments had significant influence on the core weight of the fruit. Highest core weight of the fruit was observed in T_2 (81.66) and lowest core weight was seen inT_6 (69g). It was evident from Table 2. That paclobutrazol treatments had significant influence on the crown weight of the fruit. Highest crown weight of the fruit was observed in T_2

(178.52g) and lowest peel weight was seen inT_3 (130.94g). The data on effect of paclobutrazol on pulp percent of fruits was shown in the Table 2. Examination of the results revealed that paclobutrazol manifested significant results in the pulp percent. The highest pulp percentage was seen in T_3 (60.31%) and the lowest pulp percent was seen in T_2 (56. (17%). The data on effect of paclobutrazol on peel percent of fruits was shown in the Table 2. Examination of the results revealed that paclobutrazol manifested significant results in the peel percent. The highest peel percentage was seen in control (19.03%) and the lowest peel percent was seen in T_3 (16.44%).

The data on effect of paclobutrazol on core percent of fruits was shown in the Table 2. Examination of the results revealed that paclobutrazol did not manifest significant results in the core percent. The highest core percentage was seen in control (8.24%) and the lowest core percent was seen in T_6 (7.14%).

The data on effect of paclobutrazol on crown percent of fruits was shown in the Table 3. Examination of the results revealed that paclobutrazol manifested significant results in the crown percent. The highest crown percentage was seen in T_2 (17.06%) and the lowest crown percent was seen in control (15.02%).

Results of mean data presented in Table 3. Revealed that the, paclobutrazol treatments showed significant results on fruit TSS content. Maximum total soluble solids (16.74°brix) was found in T_2 followed by T_4. Lowest TSS among all treatments was observed in T_7 (14.06°brix).

Table 2: Effect of paclobutrazol on physical parameters of fruit

Treatment	Pulp weight (g)	Peel weight (g)	core weight (g)	crown weight (g)	Pulp%	Peel%	Core%	Crown %
T_1(PBZ @ 100 ppm at 8MAP)	529.62	177.54	75	159.42	56.27	18.83	7.97	16.91
T_2(PBZ @ 100 ppm at 8 &9 MAP)	586.43	197.77	81.66	178.52	56.17	18.91	7.83	17.06
T_3(PBZ @ 200 ppm at 8MAP)	525.73	143.34	71.5	130.94	60.31	16.44	7.71	15.02
T_4 (PBZ@ 200 ppm at 8 &9MAP)	518.28	167.7	71.5	157.95	56.20	18.39	7.86	17.45
T_5 (PBZ @ 300 ppm at 8MAP)	523.08	154.78	69.34	133.78	59.64	17.58	7.83	15.20
T_6(PBZ @ 300 ppm at 8 &9 MAP)	524.45	155.71	69	140.96	58.90	17.47	7.14	15.84
T_7(Control)	506.01	167.29	72.33	131.66	57.65	19.03	8.24	15.02
S.Em(±)	13.07	4.48	2.19	3.04	0.67	0.49	12.91	0.25
C.D, at 5%	40.73	13.96	6.83	9.48	2.08	1.52	N.S	0.79

Table 3: Effect of paclobutrazol on biochemical parameters of fruit

Treatment	Total Soluble Solids (ºBrix)	Ascorbic acid content (mg/100g of fruit pulp).	Total sugars %	Reducing sugars %	Titratable acidity (%)	TSS /Acid ratio
T_1(PBZ @ 100 ppm at 8MAP)	15.37	35.48	11.21	1.65	0.625	23.77
T_2(PBZ @ 100 ppm at 8 &9 MAP)	16.74	35.88	12.42	2.35	0.613	26.73
T_3(PBZ @ 200 ppm at 8MAP)	15.47	34.9	11.02	1.51	0.64	24.16
T_4 (PBZ@ 200 ppm at 8 &9MAP)	16.32	36.8	12.26	2.79	0.665	25.97
T_5 (PBZ @ 300 ppm at 8MAP)	14.66	35.83	11.51	2.44	0.63	25.45
T_6(PBZ @ 300 ppm at 8 &9 MAP)	15.46	36.23	11.64	2.93	0.69	26.27
Control	14.06	34.81	11.01	1.46	0.67	24.59
S.Em(±)	0.16	0.39	0.11	0.10	0.02	0.42
C.D, at 5%	0.50	1.19	0.36	0.33	N.S	1.30

The data of effect of paclobutrazol on fruit ascorbic acid content is presented in the Table 3. Manifested significant difference in ascorbic acid content among treatments. Highest ascorbic acid content was found in the T_4 (36.8mg/100g) and lowest amount of ascorbic acid was found in T_7 (34.81mg/100g).

The data of effect of paclobutrazol on fruit total sugars % is depicted in the Table 3. Manifested significant difference in total sugars %. Highest total sugars content was found in the T_2 (11.42%) and lowest amount of total sugars was found in T_7 (11.01%).

The data of effect of paclobutrazol on fruit reducing sugars is depicted in the Table 3. Manifested significant difference in reducing sugars. Highest was found in T_6 (2.93%) and lowest amount of reducing sugars was observed in T_3 (1.51%).

The data pertaining to effect of paclobutrazol on Titratable acidity was depicted in the Table 3. Revealed that paclobutrazol did not inculcate significant results in the Titratable acidity. However highest Titratable acidity is seen in T_6 (0.69%).

The data of effect of paclobutrazol on TSS /Acid ratio is depicted in the Table 3. Revealed significant difference in TSS /Acid ratio. Highest TSS /Acid ratio was found in the T_2 (26.73) and lowest TSS/acid ratio was found in T_3 (24.16).

Results of mean data presented in Table 4. Revealed that the, paclobutrazol treatments showed significant results on maturity period days from fruit set to harvest. Highest number of days (123.40) required were seen in T_6 and least number of days (108.63) required for maturity were seen in control (T_7).

Results of mean data presented in Table 5. Revealed that the, paclobutrazol treatments manifested significant results crop availability period. Highest availability period (41.42 days) required were seen in T_2 and least crop availability period (21.67 days) is in control (T_7).

Discussion

Increase in fruit weight in paclobutrazol treated fruits could be a consequence of better resource mobilization as propounded by (Davis *et al.* 1988) [3]. As also manipulation of plant water relations in preference for the developing sinks (fruits) by paclobutrazol treatment. It is speculated that, paclobutrazol, while inducing growth restriction, may tend to reduce photo assimilate demand of the growing shoot in favour of superfluous sinks (fruits) (Kurian *et al.* 2001) [7]. The results obtained were in same line with (Lolaei *et al.*, 2012) [9]. Who reported application of paclobutrazol causes decreased of vegetative growth and increased of yield and signification effects of fruit quality. The increase in yield in paclobutrazol applied fruits may be due to its effect of shifting the assimilates, chlorophyll, mineral elements and soluble proteins in leaves, stem and root (Wang *et al*. 1985) [15].

The reason for increase in pulp weight in paclobutrazol treated fruits may be due to increase in sugars and due to better resource mobilization and these results were in conformity with the findings of (Sarkar *et al*. 1998) [12]. In mango.

The increase in total soluble solids might be due to increase in sugar content which depends mostly on conversion of starch on hydrolysis (Yadava *et al*. 2008) [16]. The present results achieved on total soluble solids are in conformity with the results achieved by the (Singh and Singh, 2003) [13]. and (Kurian and Reddy, 2008) [7]. The increase in ascorbic acid content in paclobutrazol treated fruit compared to control might be due to catalytic influence of paclobutrazol on bio-synthesis of ascorbic acid from sugar (Yadava *et al*. 2008) [16]. The present result is in conformity with the results achieved by (Desai and Chundawat, 1994) [4] and (Kumari *et al*. 2005) [6] in mango. Increase in the content of total sugars by paclobutrazol treatment in mango has been reported by (Abdel *et al*. 2011). Further, (Zaharah *et al*. 2013) [17]. Reported significant increase in sugars in mango fruit by abscissic acid treatment. Thus, a possible induction of abscissic acid by paclobutrazol, as reported in an earlier study (Upreti *et al*. 2013) [14] may also be another reason for increase in sugar. The present result on reducing sugars is in conformity with the results achieved by Desai and Chundawat (1994) [4] and (Hoda *et al*. 2001) [5]. Paclobutrazol, while inducing growth restriction, may tend to reduce photo-assimilate demand of the growing shoot in favour of superfluous sinks (fruits). This is expected to decrease in acidity. These results were in conformity with (Burondkar *et al*. 2013) [2].

Conclusion

Paclobutrazol altered many fruit physical parameters and also quality parameters like TSS, total sugar. Best results pertaining to fruit yield and fruit quality were obtained in paclobutrazol applied at 8 & 9 months after planting @ 100ppm. Paclobutrazol application also resulted in increase of crop availability period by 41days in T_2 which will increase the market value for fruits during offseason.

Table 4: Effect of paclobutrazol on fruit maturity period days from fruit set to harvest

Treatment	Maturity period (days)
T_1(PBZ @ 100 ppm at 8MAP)	112.86
T_2(PBZ @ 100 ppm at 8 &9 MAP)	110.46
T_3(PBZ @ 200 ppm at 8MAP)	118.44
T_4 (PBZ@ 200 ppm at 8 &9MAP)	117.86
T_5 (PBZ @ 300 ppm at 8MAP)	124.80
T_6(PBZ @ 300 ppm at 8 &9 MAP)	123.40
T_7(Control)	108.63
S.Em(±)	0.67
C.D, at 5%	2.09

Table 5: Effect of paclobutrazol on Crop availability period.

Treatment	Crop availability period (days)
T_1(PBZ @ 100 ppm at 8MAP)	37.34
T_2(PBZ @ 100 ppm at 8 &9 MAP)	41.42
T_3(PBZ @ 200 ppm at 8MAP)	31.36
T_4 (PBZ@ 200 ppm at 8 &9MAP)	34.68
T_5 (PBZ @ 300 ppm at 8MAP)	24.71
T_6(PBZ @ 300 ppm at 8 &9 MAP)	22.84
T_7(Control)	21.67
S.Em(±)	0.67
C.D, at 5%	2.08

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