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Influence of Low Concentration of Paclobutrazol and Its Application Close to the Main Trunk on Fruiting of Mango in Ultra High Density Plantations

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Authors' contributions

This work was carried out in collaboration among all authors. All three authors have participated in this field study from the planning stage of the experiments to share the field work and implemented the different treatments and collected data at harvest. All authors read and approved the final manuscript.

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ABSTRACT

Control of flowering and fruiting in mango is achieved by the application of Paclobutrazol (PBZ) in many commercial orchards. However, growers tend to use very high concentrations of the chemical, resulting in high costs of operation and long-term effects. This study examines the impact of low concentrations and varying application methods of PBZ on mango fruit yield in ultra-high-density plantations. Here 3 methods of application and 4 levels of PBZ concentrations (PBZ 23% SC) were tried in a 3 year study. Application of PBZ at N1 (close to the trunk, also termed as collar drench), N2 (20 cm away from the trunk) and N3, (1 m away from the trunk), all resulted in similar number of fruits and fruit weights. Using very low concentrations of PBZ, 4 (0.37 g a.i. /m canopy

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diameter (cd), 5 (0.46 g a.i. /m cd) and 6 (0.55 g a.i. /m cd) ml/2 liter water, it was found that the lowest 0.37 g a.i. /m cd is enough to get statistically higher fruit yield. These findings: a very low dose of PBZ can result in high productivity and a requirement of least volume of the solution when applied as a collar drench would make the use of PBZ more sustainable and encourage more growers to adopt the hormonal use for mango production.

Keywords: Paclobutrazol; mango; collar drench; ultra-high density; flowering; yield.

1. INTRODUCTION

Mango is an important fruit crop of India. Mangoes put forth vegetative flushes thrice in a year in Indian tropics. But the panicles appear in the terminal buds of the past season vegetative growth during December-January. Under tropical conditions, staggered flowering is common. Besides, cultivars like Alphonso suffer from erratic or biennial bearing habits; while cultivars like Totapuri and Ratna are regular bearers. Under favourable conditions of climate, nutrition and soil moisture content, the vegetative growth tend to continue affecting the flowering process.

Pruning the plants, immediately after harvest in June and treatment of trees with Paclobutrazol (PBZ) helps to suppress vegetative growth, and thereby induce early flowering in mangoes. Judicious pruning and treatment with appropriate dose of PBZ, ensure regulation of canopy within manageable height and promote early, uniform flowering and enhanced fruiting. Application of PBZ (a GA inhibitor), effectively reduce the canopy volume and induce uniform flowering.

PBZ is considered one of the best chemical growth regulators used for induction of flowering in mango (Nartvaranant et al., 2000). PBZ applied to the soil is used for the production management of mango in most orchards, but it is assumed that the chemical would persist in the plant and the soil. The application of PBZ caused earlier flowering by 22 days and harvesting was also done earlier by 18 days compared to the control (Rahman et al., 2023). They also reported that PBZ 1.5 g a.i /m canopy diameter with FBP (flower bud pruning) showed significantly higher flowering percentages, number of panicles, total flowers, total fruits and weight of fruit compared to the control of water treatment.

Studies have been carried out at Jain Research Farm in Udumalpet (Tamil Nadu) over two decades in both high density (3m X 2m) and medium density (4.5 m X 4.5m) plantations to regulate vegetative growth and flowering in Alphonso, Ratna, Totapuri and Kesar using PBZ. There exist two issues connected with the concentration (quantity) of PBZ chemical application: 1. the scientific reports indicate different concentrations and 2. A higher than required application rate would be deleterious to the trees and would leave residues in the soil. Besides, higher doses escalate the cost of application. Therefore as part of the research plan, the effect of different concentrations of PBZ is studied in a 3 year field experimentation to fix a specific but low concentration of PBZ that would trigger flowering and fruit set. The study also looked at if there is a carryover effect of PBZ on fruit set if application of PBZ is done in alternate year.

2. MATERIALS AND METHODS

The planned Paclobutrazol (PBZ), Cultar, manufactured by Syngenta applications were done on mango (Var. Totapuri) grafts planted in 2014 at a geometry of 3 m x 2m (Ultrahigh density) in Jain irrigation Research farm at Udumalpet, in Tirupur district, Tamil Nadu. These 5 year old trees (at the beginning of the trial in 2019) are maintained at an average height of 2.5 m and canopy diameter of 2.5 m by training and annual pruning. These trees began fruiting when they were 3 years old. In a typical crop cycle, flowering occurs in January -February and harvest takes place in May- June. Trees are then pruned in July after harvest.

In 2019 the PBZ treatments were done in the last week of September. But flowering and yield data could not be collected as further observations on these trees could not be carried out as the farm was closed due to Covid 19.

In 2020 flowering season the treatments were repeated. PBZ was applied at the end of September 2020 for the same selected trees. Usually PBZ application is followed by irrigation at the estimated crop water requirement level. Because of the rains received after the treatments in 2020 irrigation was not required

and hence not given. Flowering occurred in Jan-Feb. Harvest of this crop was done in June 2021 (6/7/21).

In 2021 again we pruned the trees in July 21. PBZ was applied in September last week to three trees only of the originally selected 6 trees in each treatment. Flowering occurred in Feb 2022. Harvest done in June (24-6-22). Fruit yields were recorded from the Paclobutrazol treated trees and non-treated trees separately.

Same cycle was repeated in 2022 and harvest was done in June –July (1/7/23). PBZ was applied to non -treated 3 trees of 2021 and the other 3 trees (those received PBZ in 2021) were not treated.

Fruit number/tree and fruit weight (kg/tree) were recorded at fruit harvest in each year in all treatments.

2.1 Paclobutrazol Treatments

There were 3 methods of application and 4 levels of Placobutrazol concentrations (PBZ 23% SC) in the treatment.

3 methods of application are:

N1 - Application in a Ring close to the trunk (collar drenching)
N2 - Ring at 20 cm away from trunk
N3 - Ring at 1 m away from trunk.
In each case the ring was 2 cm deep and 5 cm wide.

There were 4 different concentration levels of Paclobutrazol treatments.

T1 - 4 ml PBZ per plant in 2 liter water (0.37 g a.i. /m canopy diameter (cd)
T2 - 5 ml PBZ in 2 lit water (0.46 g a.i. /m cd)
T3 - 6 ml in 2 liter water /plant (0.55 g a.i. /m cd)
T4 - distilled water check.

2020: The trees were marked with color painted on the trunk based on the treatment combination for easy identification and fruit data collection.

The treatments were replicated 4 times. There are 288 trees in total, 6 trees per treatment combination per replication. All 288 trees received their respective treatment on the same calendar day in all three years.

2021: Of the 6 treated trees of 2020 (for each treatment level), first 3 trees in the row were treated with PBZ again and the rest 3 trees are given no PBZ treatment. This pattern was repeated in all treatment combinations.

2022: In 2022 we have reversed the pattern followed in 2021: first 3 trees were not treated and the last 3 trees were treated with same treatment combinations of PBZ (T1.T2.T3 and T4).

All trees received same level of fertigation and irrigation and pruning and plant protection measures. No special pest pressure or adverse event was recorded during the three year study period.

Table 1. Temperature (Max and Min. and Humidity (RH) minimum and Maximum for the treatment period during 2020, 2021, 2022 and 2023

Month	2020		2021		2022		2023	
	Temperature		Temperature		Temperature		Temperature	
	Max.^{o}C	Min.^{o}C	Max.^{o}C	Min.^{o}C	Max.^{o}C	Min.^{o}C	Max.^{o}C	Min.^{o}C
JAN	33.65	18.48	28.86	20.19	32.60	19.51	32.79	16.45
FEB	34.89	19.12	32.80	18.88	33.87	19.61	35.20	15.89
MAR	37.51	22.53	36.50	21.21	36.70	20.90	36.38	21.19
APR	38.57	23.54	36.90	23.71	36.40	23.50	38.32	26.62
MAY	37.12	24.93	36.05	24.47	34.90	31.68	37.94	26.58
JUN	35.40	24.71	34.75	24.55	34.90	24.26	37.27	27.30
JUL	34.79	24.23	38.86	24.20	33.77	23.81	34.12	23.34
AUG	34.09	23.89	33.45	24.07	33.46	22.10	36.50	25.06
SEP	33.16	23.74	34.66	23.86	34.12	23.02	34.55	24.71
OCT	34.58	23.17	33.40	23.50	33.86	22.17		
NOV	31.36	21.99	30.99	22.66	31.45	21.59		
DEC	28.44	20.48	32.42	19.90	31.33	20.83		
Mean	**34.46**	**22.56**	34.13	22.60	**33.94**	**22.74**	**35.90**	**23.02**

Month	2020.00		2021		2022		2023	
	Humidity		Humidity		Humidity		Humidity	
	9.a.m	2.p.m	9.a.m	2.p.m	9.a.m	2.p.m	9.a.m	2.p.m
JAN	74.70	45.54	81.38	69.61	79.41	51.54	71.61	50.00
FEB	77.72	38.82	72.75	50.71	75.14	42.35	65.14	39.96
MAR	78.74	32.64	69.83	34.87	71.03	34.09	75.39	36.00
APR	76.60	35.50	72.03	37.00	79.26	37.16	72.37	32.37
MAY	82.03	36.61	71.06	41.16	70.19	42.29	72.42	34.46
JUN	78.26	41.03	68.83	43.13	71.06	40.56	68.63	36.33
JUL	79.29	43.32	70.06	48.38	79.71	48.23	75.96	48.51
AUG	69.64	45.83	68.86	51.16	77.00	48.68	71.54	36.03
SEP	75.10	51.73	68.00	44.03	74.00	45.10	74.20	44.53
OCT	71.12	42.16	79.90	54.80	72.00	47.26		
NOV	80.20	59.73	86.30	62.73	81.60	58.13		
DEC	84.03	70.80	80.41	53.87	79.00	56.94		
Mean	**77.28**	**45.30**	**74.11**	**49.28**	**75.78**	**46.02**	**71.92**	**39.80**

Location: The geographical location of Jains experimental farm, Udumalpet, Tamil Nadu; geographical coordinates10-36'N and77-14' EL.

Harvest: Individual fruits from all trees in each treatment combination were harvested separately and weights recorded using an electronic weighing balance.

3. RESULT AND DISCUSSIONS

3.1 Effect of Application Method (Proximity to the Tree Trunk)

The three ways (levels) of application method as shown in the pictures (Photo 1) did not express any differential effect on fruit number or fruit weight. Application of PBZ at N1 (close to the trunk, also termed as collar drench), N2 (20 cm away from the trunk) and N3, (1 m away from the trunk), all resulted in similar number of fruits (Table 2) and same fruit weight (Table 3). There were no significant differences in these variables. This is an important result as ring application away from the trunk would require relatively higher quantity of PBZ solution which increases the cost of application. One should select collar drench (N1) as it requires a relatively lower volume of the solution. Kumar et al. (2020) reported collar drenching as the preferred application method in a study on PBZ effect on flowering in Dashehari, Chausa, Langra and Fazri varieties of mango.

Table 2. Fruit number /tree for three consecutive years, each year receiving Paclobutrazol treatment applied at different distances from the trunk (N1,N2,N3)

Treatment level	2021	2022	2023
N1	7.0 (1.1)#	4.9 (0.42)	26.0 (3.9)
N2	6.0 (0.97)	4.8 (0.52)	14.2 (2.3)
N3	5.3 (0.97)	4.4 (0.52)	20.9 (3.8)
F test (P)	0.2566	0.6458	0.0908
Sig Level	NS	NS	NS

#Figures in parenthesis are SE

Table 3. Fruit weight kg/tree for three consecutive years, each year receiving Paclobutrazol treatment applied at different distances from the trunk (N1,N2,N3)

Treatment level	2021	2022	2023
N1	3.9 (0.67)#	1.9 (0.16)	12.3 (2.1)
N2	1.9 (0.49)	1.9 (0.20)	7.0 (1.3)
N3	3.0 (0.54)	1.7 (0.19)	8.7 (1.4)
F test (P)	0.1959	0.508	0.0755
Sig level	NS	NS	NS

 # Figures in parenthesis are SE

N1: Collar drench **N2: 20 cm away** **N3: 1 m away**

Photo 1. Different methods of PBZ application

There is a very prominent difference in the number of fruits per tree and weight of fruits/tree among the years, 2021, 2022 and 2023. This is just a reflection of the good year *vs* poor year phenomenon prevalent in mango flowering and yield. We looked at the overall yield of this variety in the 500 acre farm excluding the experimental plot in these three years and found that the trend shown in the experimental trees are a reflection of the overall trend found in each year.

A close study of the mean maximum and mean minimum temperatures and relative humidity of each month did not show any specific variation among these years (2020, 2021, 2022 and 2023) (Table 1). The yield variation among years is not in any way related to the temperature or humidity regime.

3.2 Effect of Different Concentrations of PBZ

Farmers are often ill-advised and use high concentrations of PBZ in mango. First it increases the cost and then also known to make the trees quite unhealthy by excessive curtailment of vegetative growth. Thus it is critical to know the right concentration for application. Therefore we tested 4, 5 and 6 ml/2 liter water of PBZ (PBZ 23% SC) in the field trial. The control treatment was distilled water.

In all the three years the results showed that distilled water control was poor in both fruit number per tree and fruit weight per tree (Tables 4 & 5). Paclobutrazol increased fruit numbers and fruit weight /tree irrespective of the concentration and in 2021 and 2022 the differences were highly significant. In 2023 the effect of treatments was not significant. This is not surprising as in years when natural flowering incidence is very high the effect of PBZ would not be dominant. A similar observation is made by Kumar et al. (2020) in their study. The present study showed that a PBZ concentration of 4ml/2 liter water/tree (0.37g a.i. /m of cd) would be sufficient to induce flowering and fruiting in young trees. Higher concentrations (5 and 6 ml/2 liter water; 0.46 g a.i. /m and 0.55 g a.i. /m cd) of the hormone did not produce any difference in terms of fruit number and fruit weight. Comparing the results from distilled water treatment, it is clear that application of PBZ is essential for high fruiting in mango.

This study is conducted in an Ultra high density orchard; 674 trees/acre in a 3 x 2 m geometry; i.e. 6 m2 ground area/tree. Gopu & Balmohan (2015) also reported that a concentration of 1.0 g a.i. /m of cd (PBZ 23% W/W) but 2.7 times higher than the lowest concentration tried in the present study.

In greenhouse grown mango at 3 x 3 m spacing, Helmey et al. (2021) studied the effect of soil drenching and foliar spray of PBZ on a mango variety, Harumanis in Malaysia and found soil drenching at 2ml/l concentration induced early flowering and more fruits per panicle. Still higher concentrations were tried by Gohel et al. (2021) in Kesar variety of mango. Their study reported early flowering when very high concentrations of PBZ; 5.0, 8.5, 11.5 and 14.5 g a.i. /m cd were applied and found that 8.5 g a.i. /m cd is required to induce early flowering. This study however did not report yield data, though. The application of

PBZ significantly enhanced the numbers of fruits per plant, fruit weight and ultimately fruit yield per tree in both the years (2015 and 2016) in comparison to untreated pruned tree including control (Kumar et al., 2020) in Langra variety of mango. But here in this study too, the authors applied PBZ at 1.5 g a.i /m cd. While Ferreira et al. (2020) reported that the application of PBZ through irrigation system is more efficient than the conventional soil application, allowing a greater assimilation of the hormone by the plant and hence the reduction of the dose. They found that low doses (0.5 to 2.5 g a.i /m canopy diameter) of PBZ induce better physiological responses in the Tommy Atkins mango. As such the concentrations that were chosen in the present study seems to be the lowest and it certainly is very economical and would not result in any carry over effect making the hormone intervention more sustainable.

We also tried to study whether an application of PBZ in a year would have a positive effect in the following year (a second flowering season). Tables 6 and 7 show the results. In 2022 fruiting season, fruit number /tree was high in trees received PBZ in October 2021 when compared to the trees that did not receive the chemical in October 2021. Fruit weight measured in 2022 fruiting season also followed the same trend. But in 2022 the effect of concentration of PBZ were still evident in both treated (in 2021) and not treated (in 2021) trees. The significant level ($P<0.001$) of the concentration effect is evident even in the non-treated trees. While in 2023, the year with high fecundity (high flowering) the effect of PBZ is not much visible in both treated (in 2022 October) and non -treated trees. And this trend shown in 2022 by the non-treated (in 2021 October) trees continued in 2023 flowering season also.

Table 4. Fruit number /tree for three consecutive years, each year receiving Paclobutrazol treatment as per the treatment plan before the onset of flowering

Treatment levels	2021	2022	2023
T1	7.5 (0.95)#	5.7 (0.41)	18.1 (4.4)
T2	7.5 (1.1)	5.5 (0.41)	23.2 (4.3)
T3	7.3 (1.2)	5.3 (0.32)	24.6 (4.4)
T4 (dist water)	2.0 (0.30)	2.3 (0.41)	15.5 (3.3)
F test (P)	0.0004	0.00031	0.427
Sig .level	***	***	NS

 # Figures in parenthesis are SE

Table 5. Fruit weight kg /tree for three consecutive years, each year receiving Paclobutrazol treatment as per the treatment plan before the onset of flowering

Treatment levels	2021	2022	2023
T1	4.0 (0.52)#	2.2 (0.15)	7.4 (1.6)
T2	4.3 (0.73)	2.2 (0.16)	12.2 (2.6)
T3	4.0 (0.62)	2.0 (0.12)	10.2 (1.6)
T4 (dist water)	1.1 (0.19)	0.84 (0.13)	7.5 (1.7)
F Test (P)	0.0009	0.00048	0.05
Sig. level	***	***	NS

 # Figures in Parenthesis are SE

Table 6. Fruit number/tree in 2022 and 2023 with and without Paclobutrazol application before flowering the respective seasons

Treatment levels	Fruiting in 2022 with Paclo treatment in 2021 October	Fruiting in 2022 without Paclo treatment in October 2021	Fruiting in 2023 with Paclo treatment in 2022 October	Fruiting in 2023 without Paclo treatment in October 2022
T1	5.7 (0.41)#	1.9 (0.004)	18.1 (4.4)	12.3 (2.4)
T2	5.5 (0.41)	1.7 (0.003)	23.2 (4.3)	15.4 (4.1)
T3	5.3 (0.32)	1.5 (0.003)	24.6 (4.4)	14.6 (2.9)
T4 (dist water)	2.3 (0.41)	0.64 (0.001)	15.5 (3.3)	1.3 (0)
F test (P)	0.00031	0.00041	0.427	0.0076
Significance	***	***	NS	**

 # Figures in Parenthesis are SE

Table 7. Fruit weight kg/tree in 2022 and 2023 with and without Paclobutrazol application before flowering the respective seasons

Treatment levels	Fruiting in 2022 with Paclo treatment in 2021 October	Fruiting in 2022 without Paclo treatment in October 2021	Fruiting in 2023 with Paclo treatment in 2022 October	Fruiting in 2023 without Paclo treatment in October 2022
T1	2.2 (0.15)	0.72 (0.06)	7.4 (1.6)	5.5 (0.94)
T2	2.2 (0.16)	0.66 (0.04)	12.2 (2.6)	6.7 (1.7)
T3	2.0 (0.12)	0.59 (0.04)	10.2 (1.6)	6.9 (1.3)
T4 (dist water)	0.84 (0.13)	0.25 (0.02)	7.5 (1.7)	0.67 (0)
F Test (P)	0.00048	0.00041	0.051	0.0053
Significance	***	***	NS	**

 # Figures in Parenthesis are SE

Table 8. Fruit weight kg /tree for three consecutive years, each year receiving Paclobutrazol treatment applied at different distances from the trunk (N1,N2,N3)

Treatment level	Fruiting in 2022 with Paclo treatment in 2021 October	Fruiting in 2022 without Paclo treatment in October 2021	Fruiting in 2023 with Paclo treatment in 2022 October	Fruiting in 2023 without Paclo treatment in October 2022
N1	4.9 (0.42)	1.5 (0.14)	26.0 (3.9)	10.9 (2.6)
N2	4.8 (0.52)	1.4 (0.18)	14.2 (2.3)	11.8 (2.4)
N3	4.4 (0.52)	1.4 (0.14)	20.9 (3.8)	10.0(3.4)
F test (P)	0.6458	0.9666	0.0908	0.7813
Significance level	NS	NS	NS	NS

Table 9. Fruit weight kg /tree for three consecutive years, each year receiving Paclobutrazol treatment applied at different distances from the trunk (N1, N2, and N3)

Treatment level	Fruiting in 2022 with Paclo treatment in 2021 October	Fruiting in 2022 without Paclo treatment in October 2021	Fruiting in 2023 with Paclo treatment in 2022 October	Fruiting in 2023 without Paclo treatment in October 2022
N1	1.9 (0.16)	0.56 (0.05)	12.3 (2.1)	5.0 (1.1)
N2	1.9 (0.20)	0.55 (0.07)	7.0 (1.3)	5.5 (1.1)
N3	1.7 (0.19)	0.55 (0.05)	8.7 (1.4)	4.4 (1.4)
F test (P)	0.508	0.9666	0.0755	0.6614
Significance level	NS	NS	NS	NS

It is clear from the Tables 6 & 7 that a dose of PBZ 4ml/tree applied in year 1 is not affecting fruit formation in the subsequent year.

Burondkar & Gunjatte (1993) reported residual influence of PBZ with a high concentration of the chemical (5 g (20 ml) and 10 g (40 ml) of the original chemical) when applied as soil drench. They reported that the effect of a three year application persisted following the discontinuation of application for three consecutive years. In the present study, possibly because of the very low application rate (4, 5, 6 ml) there were no persistent or carry over effect on fruit weight or fruit number. Using the lowest possible concentration of the chemical is cost effective and will have no soil residue effect. Similarly, Sharma et al. (2008) after a detailed study of the soil and fruit pulp reported no residue in the soil or in the fruit pulp after continuous application of 5 consecutive years.

Both fruit number and fruit weight per tree were not affected by the application method of Paclobutrazol in any year of the 4 year study period. Application of Paclobutrazol solution at close to the trunk, 20 cm away from the trunk or even 1 m away from the trunk gave similar effect. The lack of carry over effect of PBZ continued despite the difference in application method (Tables 8 & 9).

4. CONCLUSION

Thus the present study confirms that 1. A very low concentration 4 ml/tree (0.37 g a.i./m diameter of the canopy) is sufficient to regulate vegetative growth and induce flowering resulting

in high fruit number and fruit weight in a Ultrahigh density mango orchard; 2. This dose of PBZ needs to be repeated every year to achieve regular flowering and fruit formation and 3. The very low dose of PBZ is more sustainable and economical for mango growers to adopt.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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