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The Effect of Paclobutrazol in Improving the Yield Performance of Mangosteen (*Garcinia mangostana*)

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***Abstract* – Paclobutrazol is a systemic plant growth regulator which can reduce the internode length of new shoots and causes earlier formation of terminal buds and induce flowering. A study was carried out to evaluate the effect of paclobutrazol on the flowering and yield of mangosteen (*Garcinia mangostana*). Three application rates of paclobutrazol at 50%, 100% and 125% of the manufacturer's recommended rates were applied by soil drenching surrounding the trunk base. Control (untreated) trees were not applied with paclobutrazol. Three years yield records after the treatment showed that all the three application rates were able to improve the yield of mangosteen by 132-214% and 37-106% in first and second year of harvesting, respectively. The results indicated that the trees treated with 50% of the recommended rate produced higher yield in the second year of harvesting, but yield in the first year of harvest was not much different between the rates. The results also showed that the 100% and 125% recommended rates were able to increase the total flowers and fruits production as compared to untreated trees in the first year of fruit season, meanwhile the 50% recommended rate only showed significant increase of total flowers and fruits production in second year of fruit harvesting. The yield, total flowers and fruits production in the third year after treatment showed no significant different among all the treatments. The average fruit weights were not significantly different among all the treatments during the three years of harvests. Therefore, paclobutrazol at lower dose as 50% recommended rate was suggested for mangosteen by root drenching at two years interval to improve the yield performance.**

***Keywords* – *Garcinia mangostana*, Paclobutrazol, Yield, Fruit Production, Flowering Induction.**

I. INTRODUCTION

Mangosteen (*Garcinia mangostana*) is one of the most popular seasonal tropical fruit in Malaysia. Their current cultivated area in year 2017 was at 3,671 hectares with the annum production of 12,623 tonnes and contributing RM 53 million of production value in the local fruit market [1]. The fruit season of mangosteen in Malaysia is normally fall on July-August or December-January. The production of mangosteen is inconsistent and the production is mainly depended on the drought weather stress. Therefore, a study was conducted to improve the production of mangoteen by using paclobutrazol as soil drenching to induce the flowering of mangosteen.

Paclobutrazol is a systemic plant growth regulator which able to reduce the internode length of new shoots and causes earlier formation of terminal buds and induce flowering. It is absorbed by roots and translocated in the xylem only, toward the branch tips, with little or no phloem mobility [2]. Paclobutrazol has been applied as either a foliar spray or a soil drench [3]. Paclobutrazol has been widely used in regulating the flowering and fruiting on tropical fruit especially mango [4], [5], [6] and other tropical seasonal fruit such as durian [7].

Mangosteen trees treated with lower concentration of paclobutrazol was able to induce early bearing of newly mature tree, however higher concentration of application had caused shorter branch and twisted leaves [8]. Paclobutrazol applied to mangosteen has induced early flowering by 3 months as compared to untreated trees [9]. Paclobutrazol is able to increase the yield and fruit production, but not affected the fruit quality and fruit development of mangosteen [10]. Paclobutrazol application by foliar spray seem to be more effective than soil drenching to improve the flowering, increased the fruit number and total yield of mangosteen. However, heavy

fruiting was slightly reduced the average fruit weight [11].

II. Materials and Method

The mature mangosteen trees at the age of 15 years after planting were used in this study and the treatment was carried out after fruit harvesting. The study was laid out in Randomized Complete Block Design (RCBD) with four treatments included control. Three application rates of paclobutrazol (active ingredient 250 g/L) at 50% (4.25 g a.i./tree), 100% (8.50 g a.i./tree) and 125% (10.75 g a.i./tree) of manufacturer recommended rate were used in this study to compare untreated trees (control). These three paclobutrazol application rates were diluted with 500 ml of water for each application per tree and then drenched into a furrow (5 cm in depth) surrounding the trunk base (< 30 cm). The treatments were repeated in four replications that consisted of four trees for each replicate. The total flower number, total harvested fruits, yield per tree and mean fruit weight for each fruit season in year 1 until year 3 were recorded after the single application of paclobutrazol in year 1. All the data were analyzed with Analysis of Variance (ANOVA) to determine the differences between treatments and separation with Tukey (HSD) by using Statistical Analysis System programme (SAS).

III. Results

A. *Flowers Induction*

The result showed that the 100% and 125% recommended rate of paclobutrazol application were able to induced better flowering of mangosteen and increased the total flower number in the first year after treatment by produced 1,012 and 926 flowers/tree respectively as compared to untreated trees which only produced 472 flowers/tree (**Table 1)**. Even though, the 50% recommended rate of paclobutrazol was showed increased in total flower number by produced 790 flowers/tree, however it was no significant different as compared to untreated tree (**Table 1)**. Meanwhile, the total flower number in the second year after treatment only showed significant increase in the trees treated with 50% of paclobutrazol application rate by producing 1,106 flowers/tree as compared to untreated tree at 626 flowers/tree, the 100% and 125% of paclobutrazol application rate treated trees were produced 950 and 1,008 flowers/tree respectively (**Table 1**). Paclobutrazol application not showed any significant effect in increasing the total flower number of mangosteen after third year of treatment by recorded 701, 914 and 989 flowers/tree with 50%, 100% and 125% of application rate as compared to untreated tree which produced 1,095 flowers/tree (**Table 1**).

Obviously, paclobutrazol was able to improve the flowering of mangosteen by increased 96-115% of the total flower number per tree in the first year after treatment by 125% and 100% of the recommended rate application and increased 77% of the total flower number per tree in the second year after treatment by 50% of the recommended rate (**Table 1**).

Table 1. Total flowers produced by mangosteen after induced by paclobutrazol.

Treatment	Paclobutrazol application			Number of flowers				Comparison		
code	Concentration	Rate		(no./tree)				% over untreated (T4)		
	(%)	(g a.i./tree)		Year 1	Year 2	Year 3		Year 1	Year 2	Year 3
T1	50	4.25		790 ab	1106 a	701 a		168	177	64
T2	100	8.50		1012 a	950 ab	914 a		215	152	83

Treatment	Paclobutrazol application			Number of flowers				Comparison		
code	Concentration	Rate		(no./tree)				% over untreated (T4)		
T3	125	10.75		926 a	1008 ab	989 a		196	161	90
T4	Untreated	0		472 b	626 b	1095 a		100	100	100

Values with the same letter are not significantly different at Tukey 5%.

B. *Fruit Production*

The record of total fruit produced per tree was also showed the similar trend as total flower production, where the 100% and 125% recommended rate treated trees by paclobutrazol were significantly to produce highest fruits as 374 and 334 fruits/tree respectively, followed by 50% recommended rate treated trees with 279 fruits/tree as compared to untreated trees with only 131 fruits/tree at the first year after treatment (**Table 2***)*. Meanwhile in the second year after treatment, the 50% recommended rate was the only treatment showed increased in total fruits produced at 722 fruits/tree as compared to untreated trees which only produced 313 fruits/tree. Even though, the 100% and 125% recommended rate treated trees were showed slightly higher in total harvested fruit at 427 and 478 fruits/tree, but no significant different as compared to untreated trees (**Table 2**). However, paclobutrazol application was unable to improve the fruit produced at third years after treatment by showing almost similar fruit number at 407-426 fruits/tree in treated trees as compared to untreated trees with 428 fruits/tree (**Table 2**).

Generally, paclobutrazol treated trees showed significant increase of total fruits production by 155-185% at the first year after treatment with 100% and 125% recommended rate, and 131% at second year after treatment by 50% recommendation rate. Meanwhile, lower rate of paclobutrazol application at 50% showed better fruit-set by achieved 35-65% as compared to other treatments and untreated trees which only recorded 36-47% and 28-50% respectively (**Table 2**).

C. *Yield*

All the three paclobutrazol application rates were showed improvement in yield performance of mangosteen in the first and second years after treatment. Where 100%, 125% and 50% recommended rate were produced significant higher yield as 36.6 kg/tree, 30.1 kg/tree and 27.0 kg/tree respectively at the first year after treatment as compared to untreated trees which only produced 11.6 kg/tree (**Table 3**). At second year after treatment, the 50% recommended rate treated trees showed highest yield record among the treatments by producing 54.3 kg/tree, and followed by 125% and 100% recommended rate that produced 41.0 kg/tree and 36.1 kg/tree respectively as compared to untreated tree which only produced 26.4 kg/tree (**Table 3**). However, paclobutrazol application after three years of treatment showed no significant different in yield increment by recorded only 37.9-42.9 kg/tree in treated trees is almost similar as untreated trees at 40.6 kg/tree. Generally, paclobutrazol treatment to mangosteen was able to improve greater yield performance by increasing 133-214% in the first year after treatment as compared to the second year after treatment at 37-106% (**Table 3**).

Table 2. Total fruits production of mangosteen after induced by paclobutrazol.

Treatment	Paclobutrazol application			Number of fruits				Comparison		
code	Concentration	Rate		(no./tree)				% over untreated (T4)		
	(%)	(g a.i./tree)		Year 1	Year 2	Year 3		Year 1	Year 2	Year 3
T1	50	4.25		279 ab (35)	722 a (65)	425 a (61)		213	231	99

Treatment code	Paclobutrazol application			Number of fruits				Comparison		
	Concentration	Rate		(no./tree)				% over untreated (T4)		
	(%)	(g a.i./tree)		Year 1	Year 2	Year 3		Year 1	Year 2	Year 3
T2	100	8.50		374 a (37)	427 b (45)	426 a (47)		285	136	100
T3	125	10.75		334 a (36)	478 b (47)	407 a (41)		255	153	95
T4	Untreated	0		131 b (28)	313 b (50)	428 a (39)		100	100	100

Values with the same letter are not significantly different at Tukey 5%. ( ) - % of fruit-set.

Table 3. Total yield production of mangosteen after induced by paclobutrazol.

Treatment code	Paclobutrazol application			Yield				Comparison		
	Concentration	Rate		(kg/tree)				% over untreated (T4)		
	(%)	(g a.i./tree)		Year 1	Year 2	Year 3		Year 1	Year 2	Year 3
T1	50	4.25		27.0 a	54.3 a (81.3)	41.2 a		233	206 (214)	102
T2	100	8.50		36.4 a	36.1 b (72.5)	42.9 a		314	137 (191)	106
T3	125	10.75		30.1 a	41.0 b (71.1)	37.9 a		259	155 (187)	93
T4	Untreated	0		11.6 b	26.4 c (38.0)	40.6 a		100	100 (100)	100

Values with the same letter are not significantly different at Tukey 5%. ( ) – Cumulative yield of year 1 & year 2.

The cumulative yield of the first and second year after treatment recorded 81.3 kg/tree by 50% paclobutrazol application rate, followed by 72.5 and 71.1 kg/tree with 100% and 125% application rate as compared to untreated trees which only 38.0 kg/tree. The cumulative yield increment in the first two years as compared to untreated trees has indicated that the lower paclobutrazol application rate at 50% seem to be performed slightly better than other treatments at 114%, followed by 91% and 87% yield increment in 100% and 125% application rate (**Table 3**). However, the yield increment was demonstrated a downward trend after first years of harvesting and showed no improvement at the third year of harvesting (**Figure 1**). This was indicated that the effectiveness of paclobutrazol application to improve the yield of mangosteen only sustained for two years after the single application at the first year.

D. *Average Fruit Weight*

Even though paclobutrazol application was able to improve the total fruit produced of mangosteen especially in the first year after treatment up to 185%, however it was not affecting the fruits weight by producing 96.9 g/fruit, 97.4 g/fruit and 90.3 g/fruit from the trees treated with 50%, 100% and 125% of paclobutrazol application rate as compared to untreated trees that produced almost similar weight at 93.6 g/fruit (**Table 4**). The average fruit weight in the second year after treatment seem to be decreased in all the treated and untreated trees, the 100% and 125% paclobutrazol application rate treated trees produced 84.3 and 85.9 g/fruit was almost similar with untreated tree at 83.9 g/fruit. Meanwhile, the 50% application rate treated trees produced slightly smaller fruit as 76.5 g/fruit due to heavy fruit production as 69-131% higher than others, however the fruit weight was not significant different

as compared to other treated trees and untreated trees. The fruit weight at the third year after treatment also showed no significant different between the treated trees which produced 93.2-100.9 g/fruit as compared to untreated trees with 95.0 g/fruit.

IV. Discussions

The main function of paclobutrazol application to the plants is to inhibit the gibberellin acid synthesis in the leaves, which is important to promote the vegetative growth. Paclobutrazol also well known for its characteristic activity to increase flowering and contributed to the increase of fruit formation in many perennial fruit trees [12], [13]. Normally, the plants

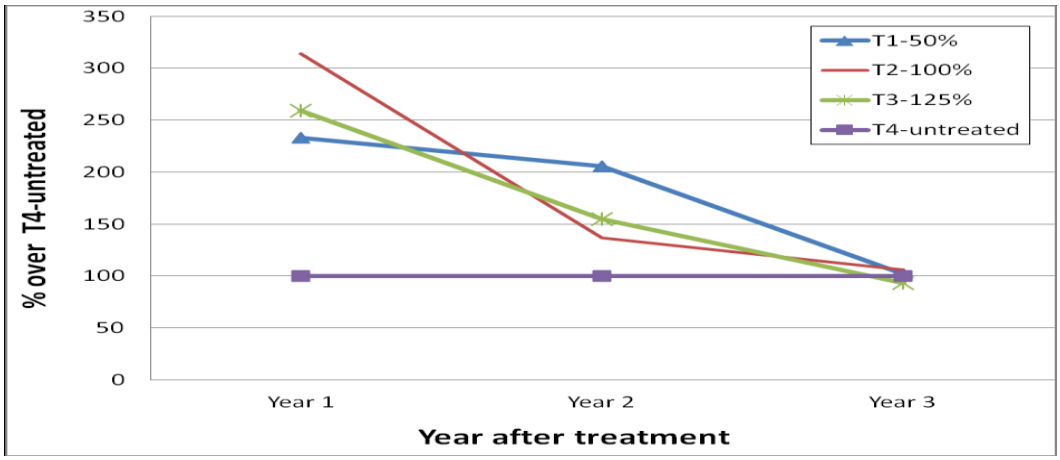

Fig. 1. Yield increment in paclobutrazol treated trees as compared to untreated during the three years after treatment period.

Table 4. Average fruit weight of mangosteen treated by paclobutrazol.

Treatment code	Paclobutrazol application			Mean fruit weight (g/fruit)				% over untreated (T4)		
	Concentration (%)	Rate (g a.i./tree)		Year 1	Year 2	Year 3		Year 1	Year 2	Year 3
T1	50	4.25		96.9	76.5	97.0		104	91	102
T2	100	8.50		97.4	84.3	100.9		104	100	106
T3	125	10.75		90.3	85.9	93.2		97	102	98
T4	Untreated	0		93.6	83.9	95.0		100	100	100
				ns	ns	ns				

ns - Not significant different.

treated by paclobutrazol showed retarded in growth and then induce flowering of the plants [14]. Apart from that, paclobutrazol also increases percentage hermaphrodite flowers, fruit set as well as yield [15]. Paclobutrazol application as soil drenching has shown significant declined of gibberellins acid and increased the C/N ratio in the leaves of mangosteen [16].

In this study, paclobutrazol was effectively retarded the vegetative growth of the treated trees as short internodes in the new branches and dense canopy were observed during the first two years of study. Paclobutrazol application has reported to reduce plant growth by influencing internode length of the leaves [17]. Characteristic of growth-retarding by paclobutrazol is largely attributed by interfering with gibberellins biosynthesis by inhibition of the

oxidation of kaurene to kaurenoic acid in the biosynthesis pathway [18]. Paclobutrazol treatment was able to sustain maximum flowering of mangosteen at 900-1,100 flowers per tree in the three consecutive years as compared to the untreated trees which only showed maximum flowering at the third year after treatment. Paclobutrazol treatments were reported able to increase the flower density, fruit set and final fruit number [19].

However, this maximum flowering of untreated trees was triggered by favourable drought stress (monthly rainfall ≤ 100 mm) with three consecutive months of dry weather as compared to the first and second year after treatment with only presented one month and two months of dry weather. Weather conditions directly affecting the flower pollination and fruit set as the high temperatures and other adverse factor could affect the pollination due to pollen and stigma susceptibility [20]. Where, mangosteen required dry period to induce heavy flowering [21].

Application of paclobutrazol has no significant effect in fruit weight of mangosteen in this study, however the fruit weight was slightly reduced during heavy fruiting in 50% recommended rate treated trees at second year after treatment. Meanwhile, some studies were also demonstrated that heavy fruiting of mangosteen induced by paclobutrazol application at 2 g a.i. per tree was reduced the fruit weight as compared to untreated trees [11], [16]. Therefore, higher fertilizer application rate was advisable for paclobutrazol treated trees especially during the heavy fruiting to sustain the fruit weight of mangosteen.

Even through, paclobutrazol was recommended as yearly application, either by soil drenching or foliar spraying to induce the flowering for fruit crops. Some study has reported, the application of paclobutrazol is the most ideal approximately at 2-3 months before actual flowering date to get profuse flowering and fruiting [22].

However, the persistence study had indicated that the residue of paclobutrazol in the soil was increased drastically from 0.065 to 2.720 µg/g soil and 0.302 to 2.954 µg/g soil after three years of continuous applied at 5 and 10 g a.i. per tree respectively [23] but the soil health will not be affected by the application of paclobutrazol [24]. Perhaps higher application rate at 4.25, 8.50 and 10.75 g a.i. that used in this study as compared to others study at 2 g a.i. per tree was caused longer residue effect in the soil that helped to prolong the effectiveness of paclobutrazol to induce flowering of mangosteen until second year after treatment by single dose application at the first year only.

V. Conclusion

Paclobutrazol application at 50%, 100% and 125% of manufacturer recommended rate were significantly to improve the flowering, increased the fruit production, total yield and sustain the average fruit weight of mangosteen as compared to untreated trees in the two consecutive years after study. However, the treatment was insignificant to show any positive response after three years of application. Paclobutrazol application at 50% recommended rate seems to be performed slightly better than higher rates in term of cumulative yield and cost effectiveness. Therefore, paclobutrazol at 4.25 g a.i. per tree (17 ml/tree) was suggested as trunk base drenching for mangosteen at two years interval to improve the yield.

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