Effect of paclobutrazol on growth and yield of cocoa high density plantings
(Kesan paklobutrazol terhadap pertumbuhan dan hasil koko penanaman kepadatan tinggi)

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Key words: Theobroma cacao L., KKM 22, high density planting, paclobutrazol, vegetative growth, yield

Abstract
An experiment was carried out to study the effects of paclobutrazol, a growth retardant, on vegetative growth and yield of cocoa (Theobroma cacao L.). It was applied as a soil drenching to 1.5-year-old KKM 22 clone planted at high density (3 333 plants/ha). Six concentrations of paclobutrazol (0, 0.125, 0.250, 0.375, 0.500 and 0.625 g b.a./L) were used. Increasing the paclobutrazol concentration from 0.375 to 0.625 g a.i./L was found to reduce plant height, stem diameter, leaf size, leaf internode and leaf area index. The results also showed that increasing the paclobutrazol concentration from 0.375 to 0.625 g a.i./L increased the fraction of sky visibility from beneath the canopy. Paclobutrazol at 0.375 g a.i./L

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was most effective in controlling vegetative growth without any adverse effect on the plant. In this way, use of paclobutrazol would reduce pruning practices. It was also found that at this concentration, the number of bearing-flower cushions increased. While, the incidence of cherelle wilt was reduced even though cherelle set increased. It then led to a larger number of mature pods and subsequently increased yield. Highest yield was achieved up to 2.06 t dry bean yield/ha for the first year of production. Therefore, soil application of paclobutrazol at 0.375 g a.i./L was found to be suitable for controlling vegetative growth and yield improvement of 1.5-year-old KKM 22 cocoa clone at high density planting. At higher concentration of 0.625 g a.i./L, it adversely affected plant growth and pod size.

Introduction

High density planting (HDP) of cocoa (*Theobroma cacao* L.) has been introduced in recent decades in Malaysia and the prospect of higher early yield was anticipated. Due to the close planting of the trees, slow growing planting materials with high productivity to avoid self-shading should be used. In apple cultivation, the practice of utilising dwarfing rootstocks and chemical growth retardants to control tree vigour have successfully produced high yields (Luckwill and Child 1973; Erez 1986). However, the dwarfing effects of rootstock on scion growth have not been detected thus far in cocoa (Tan and Mazewin 1991). Consequently, another alternative to control tree vigour in cocoa is through the use of chemical growth retardants.

Though several growth retardants have been introduced in the market in recent years, only chlormequat chloride (CCC, Cycocel), daminozide (B-nine, Alar) and ancymidol are widely used (Halevy 1985). Another growth retardant of chlorophonium (phosfon) has limited use as it can only be applied to soil. The growth retardants, which inhibit gibberellin biosynthesis or action, stimulate flower formation in woody plants (Bernier et al. 1981). Daminozide has been successfully employed for controlling tree growth, but it adversely affects fruit size (Halevy 1985). Recently, uniconazole at the rate of 0.5–1.5 g a.i. was found effective in increasing flowering and fruiting in mango but not in controlling the vegetative growth of mango MA 125 (Rukayah 1989). Paclobutrazol at lower concentration was found effective in controlling the vigour of apple, peach and plum without markedly affecting fruit size compared with other growth retardants (Quinlan 1980, 1981; Williams 1982, 1984; Webster and Quinlan 1984; Erez 1986). Paclobutrazol inhibits the biosynthesis of gibberellin by blocking the conversion of kaurene to kaurenoic acid. It can be applied either as foliar sprays, soil drench or by injection into woody plants (Sterrett 1985).

Several studies on the effects of paclobutrazol on oil palm (Ng 1986), cocoa (Teoh and Ooi 1986; Thong et al. 1986; Ho et al. 1991) and fruits such as durian (Khairudin 1986a) and mango (Khairudin 1986b; Kulkarni 1988; Rukayah 1989) have been reported. In mango, soil application of paclobutrazol at the rates of 5.0–10.0 g a.i./tree was successful in controlling excessive vegetative growth as well as increasing flowering intensity, subsequent yield and improving fruit quality (Kulkarni 1988). However, limited information is available regarding the effect of paclobutrazol in controlling tree vigour and improving yield on cocoa, especially in HDP. The objective of this study was to determine the effects of paclobutrazol in controlling vegetative growth and improving reproductive characteristic of a high yielding and vigorous cocoa clone under HDP.
Materials and methods
Cocoa clone KKM 22, which has vigorous canopy, was selected for the trial. Cocoa trees were planted at a distance of 1.5 m within rows and 2.0 m between rows, giving a planting density of 3 333 plants/ha. The cocoa trees were grown under existing 60 year-old Malayan Tall coconut spaced at 9.1 m x 9.1 m triangle on Selangor series soil. The trees were grouped into four replicates of 10 trees/treatment per replicate and were laid out in a randomised complete block design.

Six concentrations of paclobutrazol of 0, 0.125, 0.250, 0.375, 0.500 and 0.625 g a.i./L per tree were tested on 1.5-year-old trees. Each concentration of paclobutrazol was diluted to 1 000 mL with water and applied in the soil surrounding the trunk before the major flowering season (March 1992), once a year.

Before the trial, all flowering cushions (with and without flowers at the time) were tagged and numbered. Subsequently, after paclobutrazol application, any new flowering cushions that emerged were tagged weekly. Cherelles that set were also recorded and tagged on a weekly basis. At the same time, any cherelles that wilted were also recorded. The leaf area index and percentage of fraction of sky visible from beneath the canopy were measured non-destructively by a LAI-2000 plant canopy analyzer. Leaf area was determined destructively using a leaf area meter.

Results and discussion
Vegetative growth
Increasing paclobutrazol concentration reduced the plant height, stem diameter, leaf area index, leaf size and leaf internode (Figure 1). The effect was observed in the first 3 months. A drastic reduction in shoot and internode elongation using rates up to 10 g a.i. paclobutrazol per tree was reported (Thong et al. 1986).

Paclobutrazol at ≥ 0.375 g a.i./L per tree was effective in controlling tree vigour. Treated trees had limited growth and reduced canopy spread compared with trees of other treatments. Consequently, the fraction of sky visible from beneath the canopy was increased (Figure 1). Other studies also showed that paclobutrazol has a significant advantage in controlling vigour on apple, peach, plum and mango trees (Quinlan 1980, 1981; Williams 1982, 1984; Webster and Quinlan 1984; Erez 1986; Kulkarni 1988). This is important to improve the interception of light and its distribution within the cocoa canopy. Trees with small canopies have a better light interception and distribution than large, thick canopy trees in which radiation can be very low in the inner parts. The importance of radiation in relation to flowering and yield is well known (Cain 1971; Jackson 1980).

Thus, it would appear that using paclobutrazol would reduce pruning practices, especially in HDP. Under this planting system, excessive canopy structure has been a major problem. Higher concentration of paclobutrazol (0.625 g a.i./L) had adversely affected the plant growth which resulted in some plants being destroyed during the study period.

Flowering and fruiting
Generally, an increase in paclobutrazol concentration had resulted in an increase in the number of flower-bearing cushions (Figure 2). However, the only marked increase was at 0.375 g a.i./L and then there was a sharp decline with further increase of paclobutrazol concentrations. Other study also showed that in the low flowering cocoa clone (BAL 208), paclobutrazol increased flowering by 45% while the profusely flowering clone (BAL 204) showed no increase (Ho et al. 1991). It was also indicated that the increase was due to more old dormant cushions being stimulated to flower since flowering intensity and production of new flower cushions were largely unaffected. Similar beneficial effects of paclobutrazol had also been observed in mango (Kulkarni 1988; Rukayah 1989). Kulkarni (1988) also postulated that
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Figure 1. Effect of soil application of paclobutrazol on the vegetative growth of 1.5-year-old KKM 22 cocoa clone
Conc. of paclobutrazol (g a.i./L)  

Figure 2. Effect of soil application of paclobutrazol on the flowering and fruiting of 1.5-year-old KKM 22 cocoa clone

paclobutrazol could promote flowering in two ways; it could either speed up and increase the synthesis of the floral stimulus in an inductive cycle or, more possibly, affect the ratio of the flower-promoting and flower-inhibiting factors. This study also showed that increased flower-bearing cushions generally reflected the effect of paclobutrazol on cherelle sets and mature pods, especially at 0.375 g a.i./L of paclobutrazol (Figure 2).

Generally, the incidence of cherelle wilt was particularly higher with higher cherelle sets (Figure 2). However, there was no significant difference in wilting incidence at 0.375 g a.i./L compared with the control, although this concentration significantly increased cherelle sets. This might be due to less competition between the developing cherelles and vegetative growth since this concentration was effective in controlling excessive vegetative growth. Generally, wilting was believed to be associated with competition for nutrients (Humphries 1940). In other study, it was found that cherelle wilt was particularly severe during higher cherelle production and/or intensive leaf flushing (Kasran and Hashim 1992). Therefore, soil application of paclobutrazol at 0.375 g a.i./L per tree significantly increased pod production compared with the other treatments.

Yield

It was clearly shown that an increase in paclobutrazol concentrations had
Paclobutrazol effect on cocoa growth and yield

Table 1. Effect of soil application of paclobutrazol on pod characteristic of 1.5-year-old KKM 22 clone

<table>
<thead>
<tr>
<th>Conc. of paclobutrazol (g a.i./L)</th>
<th>Pod length (cm)</th>
<th>Pod width (cm)</th>
<th>Bean number/pod</th>
<th>Bean size (g/bean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>15.75a</td>
<td>8.75a</td>
<td>41.0a</td>
<td>1.10a</td>
</tr>
<tr>
<td>0.125</td>
<td>13.85b</td>
<td>8.34a</td>
<td>36.4a</td>
<td>1.19a</td>
</tr>
<tr>
<td>0.250</td>
<td>13.37b</td>
<td>8.27a</td>
<td>36.4a</td>
<td>1.21a</td>
</tr>
<tr>
<td>0.375</td>
<td>13.15b</td>
<td>8.06ab</td>
<td>36.3a</td>
<td>1.14a</td>
</tr>
<tr>
<td>0.500</td>
<td>13.08b</td>
<td>8.03ab</td>
<td>36.6a</td>
<td>1.08ab</td>
</tr>
<tr>
<td>0.625</td>
<td>12.49b</td>
<td>7.48b</td>
<td>36.7a</td>
<td>0.95b</td>
</tr>
</tbody>
</table>

Mean values with different letters in each column are significantly different at 5% level by DMRT.

markedly reduced the pod size (Table 1). Effects of paclobutrazol on bean number per pod and bean size were not clearly observed (Table 1). However, higher concentration of 0.625 g a.i./L significantly reduced the bean size. The total dry bean weight was increased at 0.375 g a.i./L, but then declined with further increase in paclobutrazol concentrations to 0.500 and 0.625 g a.i./L. (Figure 3). Highest yield was achieved with an application of paclobutrazol at 0.375 g a.i./L which corresponded to 2.06 t dry bean weight per hectare in the first year of production.

Conclusions
Soil application of paclobutrazol was effective in controlling vegetative growth and improving yield of vigorous cocoa clones under HDP. Increasing the paclobutrazol concentrations is found to reduce plant height, stem diameter, leaf size, leaf internode and leaf area index. Consequently, the fraction of sky visible from beneath the canopy was increased. In this way, use of paclobutrazol would reduce pruning practices. Concentration of 0.375 g a.i./L was suitable for 1.5-year-old KKM 22 cocoa clone. Dry bean yield of up to 2.06 t/ha was obtained in the first year of production. Higher concentration of 0.625 g a.i./L should be avoided because it adversely affected plant growth and pod size.
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