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Effects of Paclobutrazol and its Method of Application on the Growth and Transpiration of *Acacia mangium* Seedlings

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ABSTRAK

Anak benih A. mangium *berumur 10 minggu telah dikenakan pembantut tumbesaran, paclabutrazol (PP333), pada kepekatan 0, 0.5, 1, 4 dan 12 g/l. Empat kaedah telah diuji iaitu S, membasahkan tanah di minggu 0; F1, semburan daun (tanah tabung dihalang dari terkena kimia) diminggu 0; F2, semburan daun (tanah tabung dihalang dari terkena kimia) di minggu 0 dan 6; dan S + F, semburan tanah dan daun (tanah tabung tidak dihalang dari terkena kimia) di minggu 0. Pokok-pokok dituai selepas 12 minggu untuk pengukuran beberapa parameter tumbesaran. Ketinggian dan keluasan daun, transpirasi dan konduksian stomata diukur setiap minggu. Paclobutrazol didapati berkesan untuk mengurangkan tumbesaran akar dan pucuk, transpirasi dan konduksian stomata anak benih. Pokok yang dikenakan kimia tersebut mempunyai perimbangan akar: pucuk yang tinggi. Kesan kimia bertambah dengan pertambahan kepekatan dan kekerapan semburan. Kimia itu paling berkesan apabila digunakan menerusi tanah samada melalui pembasahan tanah (S) atau semburan daun dan tanah (S+F).*

ABSTRACT

Ten-week-old potted A. mangium *seedlings were subjected to a growth retardant, paclobutrazol (PP333), at concentrations of 0, 0.5, 1, 4 and 12 g/l. Four methods of application were tested namely S, soil drenching at week 0; F1, foliar spray (potting soil protected from chemical) at week 0; F2, foliar spray (potting soil protected from chemical) at week 0 and 6; and S+F, soil and foliar spray (potting soil exposed to chemical spray) at week 0. Plants were harvested after 12 weeks for various growth measurements. Height and leaf area increments, transpiration and stomatal conductance were monitored at weekly intervals. Paclobutrazol was found to be effective in reducing root and shoot growth, transpiration and stomatal conductance of the seedlings. Treated plants had higher root to shoot ratios. The effects of the chemical increased with increasing concentration and frequency of application for the foliar spray. The chemical was most effective when applied through the soil either by drenching (S) or soil and foliar spray (S+F).*

INTRODUCTION

Malaysia has a programme to establish plantations of fast-growing hardwood species, principally *Acacia mangium* Willd. for general utility timber totalling 500,000 hectares by the year 2000. The success of such a large-scale plantation establishment depends on an efficiently-managed nursery to produce high-quality planting stock which can survive and grow rapidly when outplanted. Presently, potted seedlings about 3 months old and averaging 30 cm in height are transplanted from the nursery to the field. Survival and growth of these seedlings are reported to be good, but mortality sets in when transplanting is delayed and the seedlings overgrow in size (Abod and Abun 1989). The mortalities have often been attributed to unfavourable root to shoot ratios resulting in desiccation post-transplanting. Delays in transplanting often occur because of climatic factors which affect the timing of site preparation and its synchronization with field planting. This study was conducted in an attempt to develop an effective manipulative technique for controlling the growth of *A. mangium* seedlings and improving their establishment in the field.

Researchers have for many years sought reliable, effective and safe methods of controlling shoot growth of tree species using chemical growth retardants. Several new compounds have become available for testing in the last few years, all inhibitors of endogenous gibberellin biosynthesis. One of the most potent and long-lasting, the triazole paclobutrazol, has shown great efficacy in reducing height growth of many temperate fruit species and cultivars (Webster and Quinlan 1984).

At certain concentrations and spray volumes, paclobutrazol is reported to reduce shoot but not root growth and, in some instances, to improve plant water relations (Rademacher *et al.* 1984; Wang *et al.* 1986; Atkinson 1986). Swietlik and Miller (1983) reported that root length was stimulated by paclobutrazol applications at low to moderate concentrations. Moreover, Steffens *et al.* (1983) showed increases in fibrous root length, root: shoot ratio and unsuberised root diameter of apple (*Malus domestica* Borkh.) seedlings after treatment with paclobutrazol. Higher concentrations, however, may reduce root growth (Swietlik and Miller 1983). Increases in root: shoot ratios stimulated by plant growth retardant treatment should, in theory, also improve plant water relations and increase tolerance to drought (Turner and Begg 1981). Where growth retardants are applied at concentrations sufficient to control shoot growth it is likely that most of their effects on the water economy of the plant will be attributed to the indirect effect of reduced leaf number and total leaf area (Atkinson and Crisp 1982; Asamoah and Atkinson 1985). However, both Atkinson and Crisp (1982) and Dubravec *et al.* (1986) suggested an additional anti-transpirant effect of paclobutrazol, in addition to the indirect influence on water relations by reduction in leaf area.

Several methods have been used for applying paclobutrazol to trees. These include foliar sprays, soil surface sprays, trunk drenches, soil injection in narrow bands, incorporation into potting soil and pressure injection into the vascular system of woody stems. Foliar sprays with paclobutrazol have been reported to give immediate control of apple tree growth in the United Kingdom(Quinlan and Richardson 1984),but several applications are required in a single season to obtain effective growth control (Lever *et al.* 1982). Application as a soil drench is more effective than foliar spray in the long term (Curry and Williams 1983) mainly because the chemical can persist in the soil for longer periods and is readily absorbed by the roots and translocated acropetally through the xylem to the meristematic regions (Richardson and Quinlan 1986).

MATERIAL AND METHODS

A. mangium seeds were obtained from plantations in Sabah, Malaysia that were initially established from seeds imported from Queensland, Australia.

Seeds were pretreated in boiling water for 30 seconds, soaked in tap water for 24 hours and then germinated in a greenhouse. Four weeks after germination, each seedling was transplanted into a plastic pot measuring 19 cm in diameter and 14 cm in height. The potting medium was a mixture of soil, sand and peat in a ratio of 7:3:2. Each pot contained 3 kg of the medium. To every 100 kg of the potting medium, 2 kg of triple superphosphate fertilizer was added.

The experiment was conducted in a greenhouse. Plants were selected 10 weeks after germination. Seedlings with uniform shape and measuring 20 cm tall were chosen from a large number of available plants.

Paclobutrazol (PP333) was supplied by Imperial Chemical Indusries (ICI) in aqueous suspension at a concentration of 250 g/l with an active ingredient content of 22.0% w/w. Its trade name is Cultar and chemical formula [2RS, 3RS) -1-(4-chlorophenyl)] -4, 4-dimethy1-2- (1H-1,2,4 triazol-1-yl) pentan-3-o1). The chemical was diluted in distilled water to give concentrations of 0.5, 1, 4, and 12 g/l. A surfactant (Du Pont agricultural surfactant) also supplied by ICI was added at a concentration of 2.0 ml/l.

The experiment tested the effects of 5 concentrations (inclusive of control at 0 g/l)and 4 methods of application as follows:

- S : Soil drenching at week 0 (i.e. at the start of the treatment)
- F1 : Foliar spray at week 0 (potting soil protected from chemical)
- F2 : Foliar spray at week 0 and 6 (potting soil protected from chemical)
- S+F : Foliar spray at week 0 (potting soil exposed to chemical)

The surfaces of the pots in the F1 and F2 treatments were covered with plastic sheets to shield the soil from the foliar sprays. A knapsack sprayer was used to spray the aerial parts of plants to run-off.

A total of 102 plants were used at 6 replicates per treatment. Only 6 unsprayed plants were used as a common control for all treatments.

Plants were harvested 12 weeks after treatment and measurements were taken for height (i.e. length of the main stem from the soil to the shoot apex), root collar diameter, number of branches, total leaf area, total root length, root and shoot dry weights. Roots were washed over a sieve of mesh pore size less than 1.0 mm square using pressurized tap water. Total root length was measured by a Comair root length scanner (Abod and Webster 1989; 1991). Leaf area was measured by a portable leaf area meter.

Increments in height and leaf area were monitored at weekly intervals from 3 plants selected randomly from each treatment. Measurements of transpiration and stomatal conductance were also made on these plants. Transpiration was measured gravimetrically at weekly intervals and expressed as gram water use (or water loss) per unit leaf area per week. The plants were watered to field capacity (as determined by a soil moisture meter - a voltaic probe manufactured by Plant Cove Ltd. UK) from the base by placing the base of each pot in a shallow dish of water. The pot and soil surface were then enclosed within a polythene bag, sealed around the stem base and weighed. Soil moisture status was monitored using the soil moisture meter and the plants maintained near field capacity by watering via the dish twice each day. The amount of water provided per week per plant was recorded and the pots were re-weighed at the end of each week.

By estimating approximate values for plant fresh weight increase per week, from values at planting and at harvest, and using the records of both water use and leaf area, transpiration per week was estimated.

Measurements of stomatal conductance, commencing in the first week following spraying were made on the abaxial surface of selected leaves using a steady-state porometer. This was similar to that described by Jones and Norton (1979) which measured the difference in relative humidity between inlet (maintained at zero) and outlet air flowing at a constant rate (2.5 ml/s) through a chamber enclosing 1.76 cm^2 of leaf surface. Measurements were taken between noon and 1400 hours on one fully-expanded, unshaded leaf at the approximate mid-length of the main shoot of each plant.

The experiment was designed to test the effects of paclobutrazol and its method of application in a 4 x 5 factorial using 6 replications in a completely randomized design.

RESULTS

Root and Shoot Growth

Increments in height, diameter, leaf area and number of branches, and total root length of the treated plants were statistically lower ($P < 0.05$) than the unsprayed control 12 weeks after treatment. On the other hand, the ratios of root length to leaf area and root to shoot dry weight of treated plants were significantly greater ($P<0.01$) than the control (Table 1). The effects of the chemical increased from 0.5 to 12 g/l. These patterns of response were similar at each of the 12 weekly measurements monitored for increments in height (*Fig. 1a*) and leaf area (*Fig. 2a*). Differences between treatments increased from week 1 to 12.

Soil drenching (S) or soil and foliar spray (S+F) gave similar and statistically significant reductions ($P<0.05$) in the height, diameter, leaf area and total root length and increased the ratios of root length to leaf area and root to shoot dry weights compared to the foliar spray alone at either one (F1) or two (F2) frequencies (Table 1). The number of branches formed was not significantly affected by the method of application. Two frequencies of foliar spray (F2) at week 0 and 6 gave a statistically greater reduction ($P<0.05$) in height and also increased the root length to leaf area ratio compared to the single spray at week 0. The effects of frequency of foliar spray were not significant on the other parameters measured. These patterns of response were also similar when monitored at weekly intervals for height (*Fig. 1b*) and leaf area (*Fig. 2b*) increments. Differences between the methods of application increased with time after treatment.

Statistically significant ($P<0.05$) interactions between the method of application and chemical concentration were recorded for height and leaf area increments, total root length and the ratio of root length to leaf area.

TABLE 1
Main effects of paclobutrazol on the growth of *Acacia mangium* seedlings 12 weeks after treatments for factor I (method of application) and factor II (concentration).

		Height Increment Factor (cm)	Diameter Increment (cm)	Leaf Area Increment (cm^2)	No. of Branches Increment	Total Root Length (m)	ln Ratio Root Length (cm) / Leaf Area (cm^2)		ln Ratio Root Dry Weight (g) / Shoot Dry Weight (g)	
Method of Application	Soil	4.5	0.14	88.9	3.2	22.8	3.02	(20.56)	-0.49	(0.60)
	Foliar F1	7.2	0.16	169.1	4.2	33.7	2.64	(14.12)	-0.65	(0.52)
	Foliar F2	6.1	0.16	159.1	3.7	29.4	2.78	(16.16)	-0.61	(0.53)
	Soil & Foliar	4.4	0.13	88.4	3.5	21.9	3.08	(21.88)	-0.52	(0.59)
	Sed	0.11	0.005	4.50	0.9	1.04	0.022		0.040	
F-Test		**	**	**	ns	**	**		**	
Concentration (mg/1)	0	13.3	0.20	268.7	8.3	44.3	2.44	(11.55)	-0.78	(0.45)
	.5	5.0	0.16	128.5	3.3	26.8	2.83	*17.00)	-0.64	(0.52)
	1	4.3	0.14	99.8	2.8	25.2	2.91	(18.49)	-0.57	(0.56)
	4	2.7	0.13	71.5	2.1	20.3	3.06	(21.52)	-0.41	(0.66)
	12	2.5	0.12	63.3	1.8	18.2	3.15	(23.51)	-0.46	(0.63)
	Sed	0.12	0.006	5.03	0.44	1.16	0.025		0.044	
F-Test		**	**	**	**	**			**	

Error df=40 *$p<0.05$ **$p<0.01$ ns: not significant

Bracketed means are retransformed values.

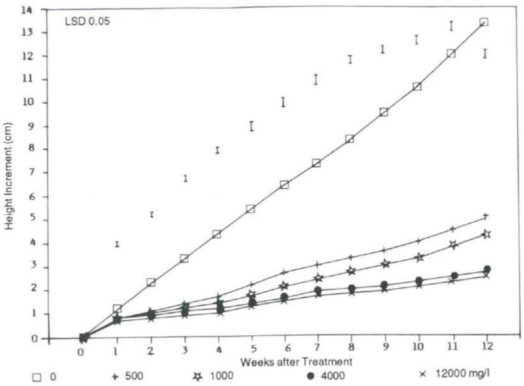

Fig. 1a: Effect of concentration of paclobutrazol on the height increment of Acacia mangium *seedlings*

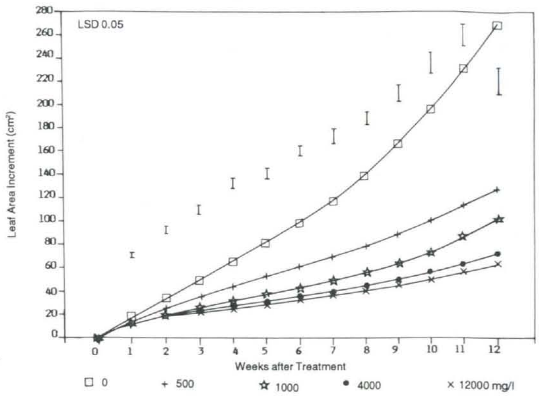

Fig. 2a: Effect of concentration of paclobutrazol on the leaf area increment of Acacia mangium *seedlings*

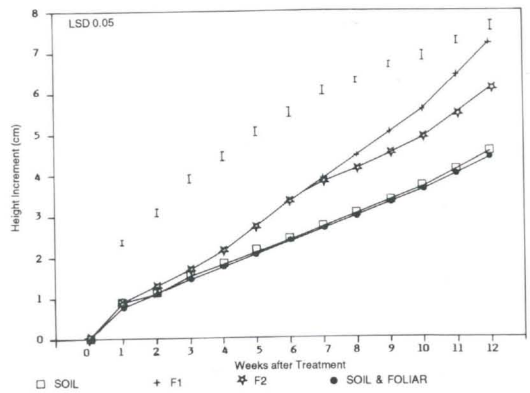

Fig. 1b: Effect of method of applying paclobutrazol on the height increment of Acacia mangium *seedlings*

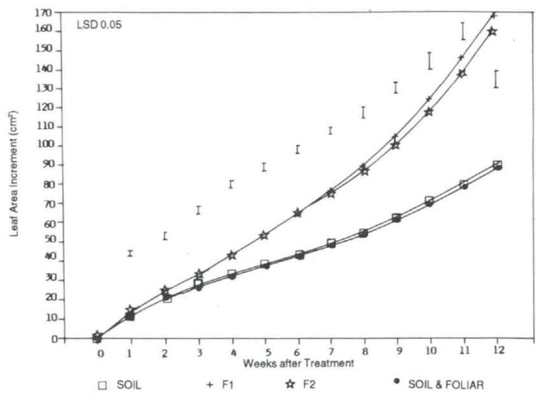

Fig. 2b: Effect of method of applying paclobutrazol on the leaf area increment of Acacia mangium *seedlings*

Transpiration and Stomatal Conductance

Both transpiration (*Fig. 3a*) and stomatal conductance (*Fig. 4a*) of treated plants were lower than the control throughout the 12 weekly measurements. Complete recovery was not apparent for either parameter at any of the concentrations 12 weeks after treatment. Stomatal conductance, however, appeared to recover to higher values from week 7 and this was most apparent at 4 and 12 g/l (*Fig. 4a*). Lowest transpiration and stomatal conductance were recorded at 12g/l and the values increased with decreasing chemical concentrations. Differences in values between the 4 and 12 g/l concentrations for either transpiration or stomatal conductance were generally not statistically significant, but the two higher concentrations induced significantly lower values than the lower concentrations (i.e. 1 and 0.5 g/l) at all sampling times.

Soil drenching (S) or soil and foliar spray (S+F) proved to be equally effective methods in reducing the transpiration (*Fig. 3b*) and stomatal conductance (*Fig. 4b*) compared to the foliar sprays at either one (F1) or two frequencies (F2) at all times of measurement. Compared to F1, the second spray in F2 significantly reduced both transpiration and stomatal conductance from week 7 to 12. Differences between the methods of application generally increased with time for both transpiration (*Fig. 3b*) and stomatal conductance (*Fig. 4b*).

Except at week 10 and 11, no statistically significant interactions were recorded between the method of application and concentration for transpiration. On the other hand, highly significant ($P<0.01$) interactions occurred between the two factors at each of the 12 weekly measurements for stomatal conductance.

DISCUSSION

Paclobutrazol was effective in retarding the root and shoot growth, transpiration and stomatal

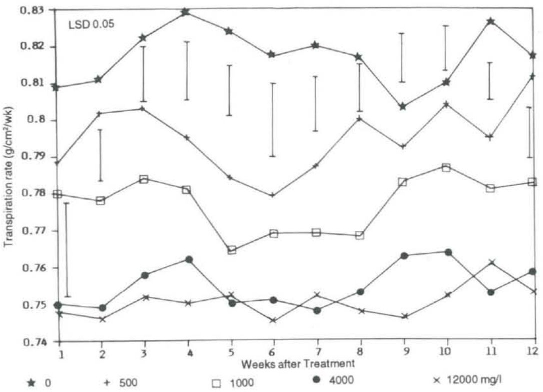

Fig. 3a: Effect of concentration of paclobutrazol on the weekly transpiration rate of Acacia mangium *seedlings*

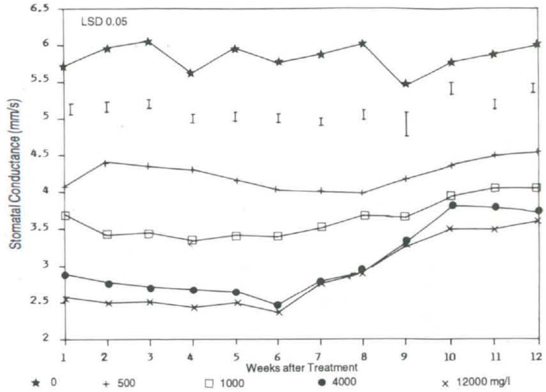

Fig. 4a: Effect of concentration of paclobutrazol on the stomatal conductance of Acacia mangium *seedlings*

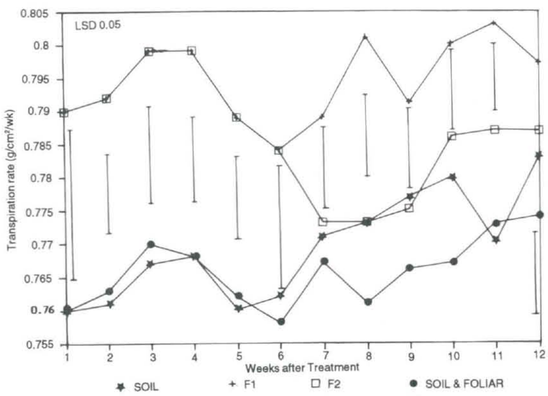

Fig. 3b: Effect of method of applying paclobutrazol on the weekly transpiration rate of Acacia mangium *seedlings*

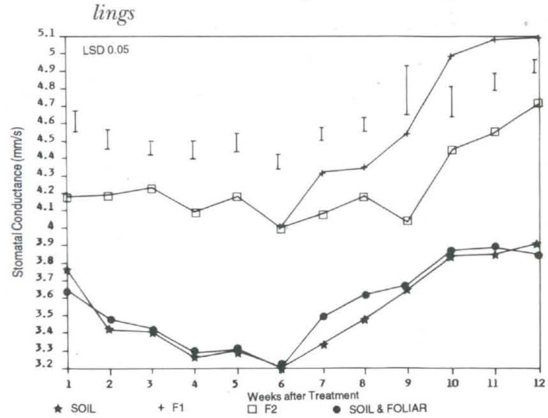

Fig. 4b: Effect of method of applying paclobutrazol on the stomatal conductance of Acacia mangium *seedlings*

conductance of *A. mangium* seedlings. The effects of the chemical increased from 0.5 g/l to reach a maximum at 12 g/l over the range of concentrations tested. No treatment damaged or deformed any seedling. Weekly measurements of height and leaf area increments and transpiration and stomatal conductance revealed the differences in values of treated plants compared to the control increased with time. There was no complete recovery for any of the parameters even at the lowest concentration tested 12 weeks after treatment. A lower concentration than 0.5 g/l appears necessary to obtain an earlier recovery from the chemical effect. The results also revealed that the soil needs to be exposed to the chemical during foliar sprays for more effective control of growth, transpiration and stomatal conductance.

Paclobutrazol-treated *A. mangium* seedlings had higher root to shoot ratios. Asamoah and Atkinson(1985) attributed such a response to a shift in assimilate partitioning from shoots to roots. The chemical also reduced the rate of transpiration. This reduction correlated well with reduced stomatal activity and decreased leaf area. Treated plants had higher root length to leaf area ratios. Atkinson and Thomas (1985) and Abod and Webster (1989) claimed that plants with these attributes have a greater chance to survive following transplanting because of improved plant water relations.

Paclobutrazol was found to be most effective in retarding the growth, transpiration and stomatal conductance of *A. mangium* seedlings when applied to the soil. This may be attributed to the chemical being readily absorbed by the roots and translocated almost exclusively in the xylem acropetally to the meristematic regions (Richardson and Quinlan 1986). The binding nature of the chemical with the soil colloidal particles might account for the greater persistence of its effects observed in this study. Conversely, paclobutrazol when sprayed onto the foliage of young plants, merely accumulates in leaves and is not translocated into other shoot tissues; the quantity of chemical reaching the sites of action is often reduced.

Two foliar sprays were more effective than one in reducing the growth, transpiration and stomatal conductance of *A. mangium* seedlings. Abod and Leong (1989) suggested that the uptake and translocation of the chemical at the second spray additively act together with the remaining triazole compounds from the previous application. In *Prunus domestica* L., Webster and Quinlan (1984) observed that a second foliar spray of paclobutrazol at 1.5 g/l consistently produced a greater reduction in shoot growth.

Paclobutrazol appears to have a potential for increasing the quality of *A. mangium* seedlings and improving its establishment post-transplanting. Further work is required to develop blueprints for treatment chemical, concentration, method of application and their implications to the production and establishment of *A. mangium* seedlings in the field.

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