EFFECTS OF A GROWTH RETARDANT AND SHOOT PRUNING ON THE GROWTH OF *ACACIA MANGIUM* SEEDLINGS

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SHEIKH ALI ABOD & CHEONG KOK LEONG. 1994. Effects of a growth retardant and shoot pruning on the growth of *Acacia mangium* seedlings. Two experiments of chemical manipulation using a growth retardant, paclobutrazol, and a physical manipulation by shoot pruning were conducted in an attempt to develop an effective nursery technique to control excessive growth of *Acacia mangium* seedlings prior to transplanting. The first experiment involved foliar spraying of 10-week-old seedlings with paclobutrazol at concentrations of 0, 0.25, 0.5, 1, 2, 4, 8 and 12 $g\,l^{-1}$ in the presence of a Du Pont agricultural surfactant. The effects of two frequencies of application were also tested. Twelve weeks after treatment, factorial analyses revealed the main effects of concentration and frequency of application to be significant in reducing the plant height, leaf area, shoot and root dry weights and increasing the root length to leaf area ratio. Only the main effects of concentration were statistically significant in reducing the diameter increment and total root length. No interactions were recorded between the two factors for most of the parameters measured and effects on growth appeared additive. Growth retardation increased with increasing chemical concentration to a maximum at 12 $g\,l^{-1}$. The second experiment tested the effects of pruning the main shoot of 10-week-old seedlings at 0, 30 and 60% of their total length before planting out. Similar growth parameters as for the first experiment were monitored for 12 weeks and the results showed maximum reduction in plants with 60% shoot removed. The effect of shoot pruning was statistically significant for all the parameters measured except for height increment and root to shoot ratios. Chemical control of growth was more promising than shoot pruning.

Key words: *Acacia mangium* - planting stock - growth control

SHEIKH ALI ABOD & CHEONG KOK LEONG. 1994. Kesan satu perencat pertumbuhan dan pemangkasan pucuk pada pertumbuhan anak benih *Acacia mangium*. Dua eksperimen di jalankan untuk menghasilkan teknik tapak semaian yang berkesan untuk mengawal pertumbuhan berlebihan anak benih *A. mangium* sebelum pemindahan dari tapak semaian. Eksperimen ini termasuklah manipulasi kimia dengan penggunaan perencat pertumbuhan, iaitu paklobutrazol dan pemangkasan pucuk sebagai manipulasi fizikal. Kajian pertama melibatkan penyemburan daun anak benih *A. mangium* yang berumur 10 minggu dengan paklobutrazol pada kepekatan 0, 0.25, 0.5, 1, 2, 4, 8 dan 12 $g\,l^{-1}$. Bahan aktif permukaan pertanian Du Pont juga digunakan. Keberkesanan penyemburan sebanyak dua kali turut di uji. Dua belas minggu setelah rawatan, analisis faktorial menunjukkan bahawa kesan utama kepekatan dan kekerapan penyemburan adalah ketara dalam mengurangkan ketinggian pokok, luas daun, berat kering akar dan pucuk dan menambahkan nisbah panjang akar dengan luas daun. Hanya kesan utama kepekatan adalah ketara dari segi statistik dalam mengurangkan kenaikan diameter dan jumlah panjang akar. Tiada interaksi yang direkodkan antara kedua-dua faktor (kepekatan dan kekerapan penyemburan) untuk kebanyakan daripada parameter yang diukur dan kesan pada pertumbuhan nampaknya bertambah. Kerencatan pertumbuhan bertambah dengan bertambahnya kepekatan kimia sehingga had maksimum pada 12 $g\ l^{-1}$. Eksperimen kedua menguji keberkesanan pemangkasan pucuk anak benih *A. mangium* yang berumur 10 minggu pada 0, 30 dan 60% daripada jumlah panjangnya sebelum dikeluarkan dari tapak semaian. Parameter-parameter pertumbuhan yang diuji adalah sama seperti mana yang dibuat pada kajian manipulasi kimia. Selepas dua belas minggu, pemangkasan pucuk sebanyak 60% menunjukkan pengurangan yang maksimum. Kaedah pemangkasan pucuk memberikan kesan yang ketara bagi semua parameter yang diuji kecuali pada penambahan ketinggian dan nisbah akar dengan pucuk. Pengawalan pertumbuhan dengan menggunakan bahan kimia memberikan harapan yang lebih berbanding dengan pengawalan pertumbuhan dengan pemangkas pucuk.

Introduction

Malaysia has a programme to establish plantations of fast-growing hardwood species, principally *Acacia mangium* for general utility timber. The success of such 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 three months old and averaging 30 *cm* in height are transplanted from the nursery to the field. Survival and growth of these seedlings in the field are reported to be good but mortality sets in when transplanting is delayed and the seedlings over-grow in size (Abod & Abun 1991). Delay in transplanting often occurs because of climatic factors which affect the timing of site preparation and its synchronization with field planting. In view of this, it is envisaged that the development of some manipulative techniques for controlling the size of *A. mangium* seedlings would be useful.

Two experiments are reported here. The first and major experiment investigated the use of growth retardant, paclobutrazol (PP 333 or Cultar) (Abod & Webster 1990); the second tested the effects of shoot pruning. The effects of these manipulative methods on the growth of *A. mangium* seedlings were evaluated for potential practical application.

Paclobutrazol is a triazole which has been reported to be a reliable, effective and safe chemical for reducing the shoot extension and leaf area of many temperate trees by inhibiting their gibberellin biosynthesis (Richardson & Quinlan 1986). Shoot pruning, on the other hand, is a common cultural method practised to increase the root to shoot ratio of planting stock with a view to reducing potential water loss by transpiration. Root pruning of potted stocks appears impractical although the technique has been reported to be very effective in controlling the size of bare-rooted *Pinus radiata* seedlings (Van Dorsser & Rook 1972).

Materials and methods

Acacia mangium seeds were supplied by the Sabah Forestry Development Authority from their plantations at Ulu Kukut, Sabah. These plantations were initially established from seeds imported from Queensland, Australia.

Seeds were pre-treated in boiling water for half a minute, soaked in tap water for 24 *h* and then germinated in sand in a greenhouse. Four weeks after germination, each seedling was transplanted into a black ploythene bag measuring 6 *cm* diameter and 18 *cm* height. The potting medium was a mixture of soil, sand and peat in a ratio of 7:3:2. All plants were given adequate water and nutrients throughout the duration of the experiments.

Potted seedlings were kept in the greenhouse for four weeks to protect them from heavy rain and full sun before being moved into the open. Plants were selected for the experiments when they were ten weeks old. Uniformly sized plants, 23 *cm* tall, were chosen from a large number of available plants.

Experiment 1: Effects of paclobutrazol (PP 333) on growth

Paclobutrazol (PP 333) was supplied by the Imperial Chemical Industries (ICI) in an aqueous suspension at a concentration of 250 $g\,l^{-1}$ with an active ingredient of 22.9% w/w. Its trade name is cultar and chemical formula [(2RS, 3RS)-1-(4-chlorophenyl)]-4, 4-dimethyl-2-(1H-1, 2,4 triazol-1-yl) pentan-3-ol. The chemical was diluted in distilled water to give a wide concentrations range, *i.e.*, 0, 0.25, 0.5, 1, 2, 4, 8 and 12 $g\,l^{-1}$.

Two frequencies of spray, *i.e.*, at week 0 and weeks 0 and 6, were tested. The aerial parts of plants were sprayed to run-off using a knapsack sprayer. No effort was made to cover the soil surface of the pots and inevitably, the chemical was also deposited on the soil medium. A total of 80 seedlings were used. There were five replicates per treatment.

Experiment 2: Effects of shoot pruning on growth

This experiment was conducted one month after the start of Experiment 1. Thirty 10-week-old seedlings were selected for the experiment. It consisted of three treatments with 10 replicates each as follows:

Control, intact shoot : 0% SP
30% of the total length of shoot pruned : 30% SP
60% of the total length of shoot pruned : 60% SP

Measurement of growth parameters

Plants in both Experiment 1 and 2 were harvested 12 weeks after treatment and measurements were taken of height (*i.e.*, total length of stems), root collar diameter, leaf area, number of branches, total root length, shoot and root dry weights, and ratios of root length to leaf area and root to shoot dry weights. Increments in height and leaf area at weekly intervals were also monitored for Experiment 1. Leaf area of either intact leaves or detached (at harvest) was measured by a portable leaf area meter. Roots were washed over a sieve of mesh pore size less than 1.0 mm^2 using pressurised water. Total root length was measured by a Comair root length scanner (Abod & Webster 1989).

Experimental design and statistical analyses

Both experiments 1 and 2 followed a completely randomised design. All data were subjected to analyses of variance (ANOVA). Experiment 1 was analysed factorially with concentration as factor 1 and frequency of spray as factor 2. Experiment 2 was analysed as a one-way ANOVA.

Results

Experiment 1. Effects of paclobutrazol on growth

Effects of concentration

The main effect of paclobutrazol concentration was significant for all the growth parameters measured except for the ratio of root:shoot dry weight (Table 1). Maximum height, diameter, leaf area, root length, and root and shoot dry weights were recorded in the control trees. These growth parameters decreased with an increase in the concentration from 0.25 $g\,l^{-1}$ to reach a minimum at the highest concentration of 12 $g\,l^{-1}$. The reverse was true for the ratios of root length : leaf area and root : shoot dry weight.

Increments in height (Figure 1) and leaf area (Figure 2) of the control trees were consistently greater than the treated. Differences between treatments increased with time after the chemical spray. Both parameters showed small differences between treatments for concentrations greater than 1 $g\,l^{-1}$ at all times of measurement over the 12- week period.

Effects of frequency of application

A greater reduction in the root and shoot growth and a greater increase in the root : shoot ratios could be achieved with two sprays compared with one (Table 1). However, the effects were statistically significant only for the height and leaf area increments, root and shoot dry weights and the ratio of root length to leaf area.

Interaction between concentration and frequency of spray

In general, the results indicated that the effects of concentration and frequency of spray were additive for all the parameters measured. Significant interactions were, however, recorded for height increment, root dry weight and root : shoot dry weight ratio. The effects of two sprays were less at higher concentrations of paclobutrazol.

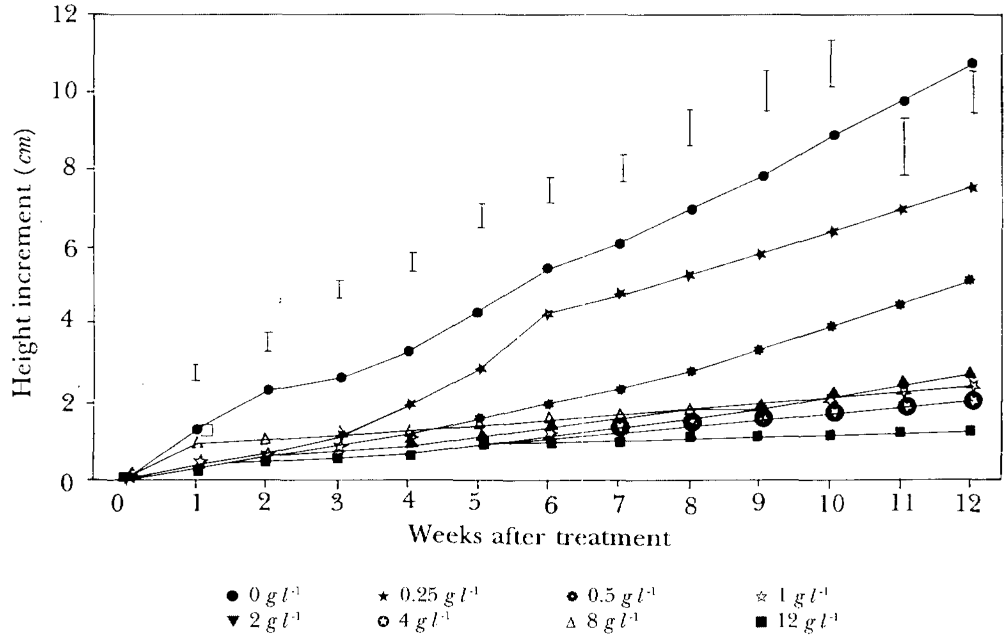
Experiment 2 : Effects of shoot pruning on growth

Maximum root and shoot growth occurred in seedlings with intact shoots and was at a minimum in trees with 60% of the shoots initially removed. The effect of

Table 1. Main effects of paclobutrazol on the growth of *Acacia mangium* seedlings 12 weeks after treatment for factor I (concentration) and factor II (frequency)

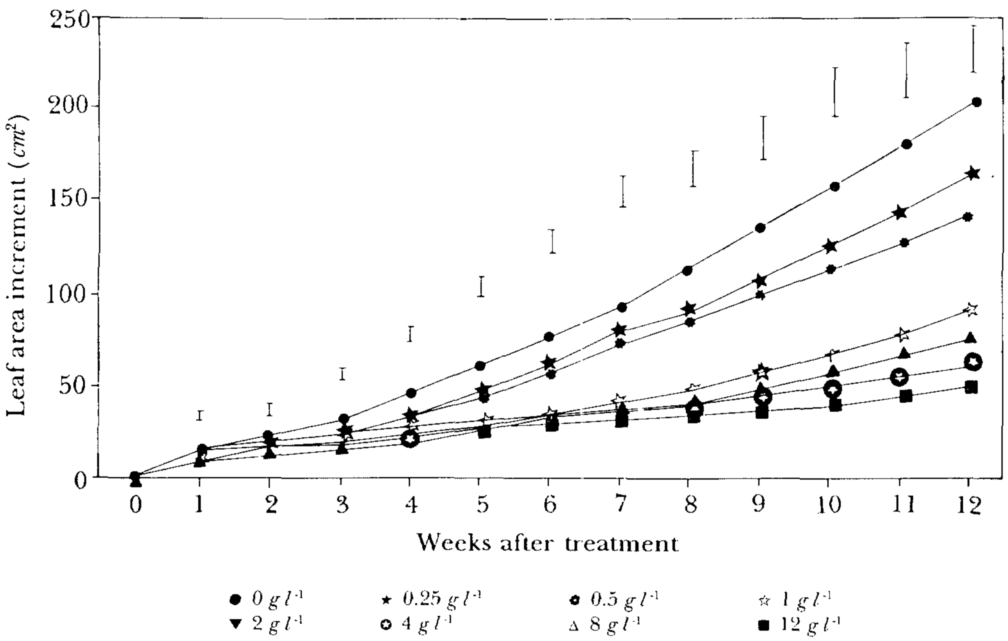
Factor		Height increment (*cm*)	Diameter increment (*cm*)	Leaf area increment (*cm*)	Total root length (*m*)	Total shoot dry weight (*g*)	Total root dry weight (*g*)	ln Ratio Total root length (*cm*) / Total leaf area (*cm*)	ln Ratio Total root dry weight (*g*) / Total shoot dry weight (*g*)
Concentration ($g\ l^{-1}$)	0	10.7	0.10	206.4	35.6	2.65	1.22	2.85 (17.36)	- 0.80 (.44)
	0.25	7.4	0.10	166.2	28.0	2.37	0.99	2.86 (17.50)	- 0.88 (.41)
	0.5	5.1	0.08	143.5	33.9	2.21	1.13	3.15 (23.52)	- 0.69 (.49)
	1	2.5	0.07	93.6	29.5	1.85	0.93	3.54 (34.47)	- 0.68 (.50)
	2	2.5	0.08	78.9	26.0	1.96	0.86	3.53 (34.36)	- 0.82 (.43)
	4	2.0	0.07	64.2	20.0	1.52	0.75	3.45 (31.72)	- 0.77 (.46)
	8	2.3	0.07	76.8	23.3	1.73	0.94	3.44 (31.22)	- 0.58 (.55)
	12	1.2	0.06	50.8	22.0	1.66	0.81	3.75 (42.78)	- 0.75 (.47)
F-test	Sed	0.50	0.008	13.3	3.33	0.236	0.118	0.142	0.115
		**	**	**	**	**	*	**	ns
Frequency of spray	1	5.1	0.08	134.8	28.9	2.17	1.05	3.14 (23.17)	- 0.72 (.48)
	2	3.3	0.08	85.1	25.7	1.82	0.86	3.50 (33.38)	- 0.77 (.45)
F-test	Sed	0.25	0.004	6.63	1.66	0.118	0.059	0.071	0.058
		**	ns	*	*	**	*	**	ns

*, $p < 0.05$; **, $p < 0.01$; ns is not significant; bracketed means are retransformed values;
1 = sprayed once at week 0; 2 = sprayed twice at weeks 0 & 6; Sed is standard error difference.



Bars indicate LSD values at $p < 0.05$ derived from ANOVA each week

Figure 1. Main effect of concentration of paclobutrazol on the weekly height increment of *Acacia mangium* seedlings



Bars indicate LSD values at $p < 0.05$ derived from ANOVA each week

Figure 2. Main effect of concentration of paclobutrazol on the weekly leaf area increment of *Acacia mangium* seedlings

Table 2. Effects of shoot pruning on 10-week-old *Acacia mangium* seedlings 12 weeks after treatment

Treatment	Height increment (*cm*)	Diameter increment (*cm*)	Leaf area increment (*cm*)	Total root length (*m*)	Total shoot dry weight (*g*)	Total root dry weight (*g*)	ln Ratio Total root length (*cm*) / Total leaf area (*cm*)	ln Ratio Total root dry weight (*g*) / Total shoot dry weight (*g*)
Intact shoot	12.0	0.11	196.5	41.5	3.26	1.43	3.28 (26.71)	- 0.91 (.40)
30% Shoot -prunned	11.5	0.03	107.1	22.8	1.38	0.59	2.87 (17.76)	- 0.86 (.42)
60% Shoot -prunned	11.0	0.01	62.2	17.1	0.64	0.37	3.27 (26.31)	- 0.47 (.62)
Sed	3.05	0.009	18.99	4.91	0.228	0.155	0.203	0.217
F-test	ns	**	*	*	**	**	ns	ns

*, $p < 0.05$; **, $p < 0.01$; ns is not significant; bracketed means are retransformed values; Sed is standard error difference.

shoot pruning was statistically significant only for diameter and leaf area increments, total root length and root and shoot dry weights. Interestingly, compared to the control trees, height increment and root length : leaf area ratio were relatively unaffected even by a severe 60% shoot pruning 12 weeks after treatment (Table 2).

Discussion

Effects of paclobutrazol

Paclobutrazol appeared to be very effective in controlling the growth of *A. mangium* seedlings. The concentration of the chemical greatly influenced the magnitude of the growth responses. Both root and shoot growth decreased with an increase in the concentration of paclobutrazol from 0.25 to 12 $g\,l^{-1}$. The converse was true for root : shoot ratios. Differences between treatment means for most of the growth parameters were not significant for concentrations greater than 1 $g\,l^{-1}$ suggesting the adequacy of using low concentrations for effective growth control.

Greater growth reductions and a larger increase in the root length : leaf area ratio were achieved with two sprays compared with one. It is probable that the uptake and translocation of paclobutrazol at the second spray additively acted together with the remaining triazole compounds from the previous application for a more effective growth retardation. In *Prunus domestica*, Webster and Quinlan (1984) found a double spray of paclobutrazol at 1.5 $g\,l^{-1}$ produced a greater effect on shoot growth.

Working with *Malus domestica*, Quinlan and Richardson (1984) showed that foliar sprays of paclobutrazol reduced shoot growth as a result of the chemical being taken up by the shoot tip and young unlignified shoot stem. Paclobutrazol has also been found to be effective in controlling the shoot growth of apple trees when applied as a soil drench (Tukey 1984). Studies on the uptake and translocation of paclobutrazol in apple trees by Richardson and Quinlan (1986) showed that the chemical is taken up through the xylem and translocated acropetally to the meristematic regions. Growth inhibition from foliar application of paclobutrazol in this study may have resulted from the absorption by the young stems and leaves as well as by the roots (since the pot soil was not covered during application) with the subsequent acropetal translocation of PP333 to the meristematic areas of plant organs. The increase in the ratio of root length to leaf area of treated plants is likely to be due to the differential growth of the roots and leaves. However, differences in the dry weight ratio of root to shoot were less apparent and not statistically significant between treatments. Atkinson and Thomas (1985), and Abod and Webster (1989) reported that the relationship between total root length and total leaf area is important in characterising the potential for plants to establish successfully after transplanting. The ratio of root length to leaf area may be as important as the size of the root system itself in defining plant water needs and in influencing plant survival and growth.

For many of the parameters tested, none of the plants showed complete recovery, even those treated with the lowest concentration of 0.25 $g\,l^{-1}$ as measured

12 weeks after treatment. Further work is required to develop blue prints for growth regulator, concentration and method application.

Effects of shoot pruning

Shoot pruning at transplanting is normally practised to compensate for the loss of roots and is an attempt to reduce potential water loss by transpiration. A high root length: leaf area ratio is particularly important for the survival of newly-transplanted trees because the most common cause of death after transplanting is desiccation caused by excessive water loss by transpiration before an effective water absorbing root surface is developed (Abod & Webster 1989, Abod & Abun 1991). The effect of shoot pruning was, however, found to be ineffective in reducing the height increment or increasing the ratios of root length to leaf area or root to shoot dry weights of *A. mangium* seedlings 12 weeks after treatment. This is in agreement with the report by Young and Werner (1982) that shoot pruning of plants stimulates rapid new shoot growth.

Differences between the heights of shoot-pruned and unpruned trees in this study were minimal at harvest whereas differences in stem diameter, total leaf area, total root length and root and shoot dry weights were statistically significant. Young and Werner (1982) and Johnson *et al.* (1984) attributed differential growth of plant parts to a competition for assimilates and nutrients, with larger growth of an organ indicating success in competition at the expense of other organs. Kramer and Kozlowski (1979) attributed a growth reduction of shoot-pruned trees to reduced photosynthesis and impairment of related metabolic processes because of injury. Perhaps shoot pruning may be effective in reducing the excessive size of *A. mangium* shoots to facilitate transplanting if carried out just prior to, or at the time of, outplanting. Further research is, however, warranted to ascertain if the practice is detrimental to the success of tree establishment in Malaysia.

A comparative assessment between the physical and chemical methods of growth manipulation

Abod and Abun (1991) reported that shoot pruning of *A. mangium* seedlings can initiate the development of multiple leaders thereby reducing plant quality. As this is contrary to the results of the present study, a repeat of the experiment is necessary. Both the shoot-pruned and paclobutrazol-treated plants had a single leader throughout the duration of the experiment.

In general, the results show that, the chemical rather than the physical method of controlling the growth of *A. mangium* seedlings for plantation establishment in Malaysia is more promising. Unlike the effects of paclobutrazol, a drastic 60% removal of the shoot failed to reduce the height increment or increase the root length to leaf area ratio of seedlings 12 weeks after treatment. In addition, shoot pruning is labour intensive. The availability of a range of growth regulators, methods of application and/or differing concentrations certainly offers more scope for the use of chemical growth manipulation compared to the cultural methods.

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