EFFECT OF ROOT-WRENCHING AND CONTROLLED WATERING ON GROWTH, DROUGHT RESISTANCE AND QUALITY OF BARE-ROOTED SEEDLINGS OF *ACACIA MANGIUM*

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Received August 1988

KAMIS AWANG & DE CHAVEZ, C. G. 1993. Effect of root-wrenching and controlled watering on growth, drought resistance and quality of bare-rooted seedlings of *Acacia mangium*. The possibility of conditioning and hardening bare-rooted *Acacia mangium* seedlings by root wrenching and controlled watering was investigated. Ten-week-old seedlings in open beds were subjected to combined treatments of three root wrenching regimes (unwrenched, wrenched fortnightly, wrenched monthly) and two watering regimes (once every three and six days). Potted seedlings with daily watering were used as controls. Twelve weeks later, the seedlings were assessed for dry matter production, root/shoot ratio, root growth capacity, diameter and height growths, diameter/height ratio, water relations and survival. Root wrenching and controlled watering had significant effects on most of the growth parameters. Good survival was associated with high root/shoot ratio, diameter/height ratio, root growth capacity and efficient water economy. Good survival was observed in seedlings watered every six days and wrenched either monthly or fortnightly. Control seedlings which had high shoot development but low root growth capacity and poor water economy showed low survival rates. Unwrenched bare-rooted seedlings watered every three days had poor survival compared to unwrenched seedlings watered every six days. Monthly wrenched seedlings had only slightly better survival results than fortnightly wrenched seedlings, indicating that increased frequency did not necessarily improve survival. A combination of monthly wrenching and 6-day watering is recommended.

Key words: *Acacia mangium* - root wrenching - controlled watering - growth - water relation - survival - conditioning - hardening

KAMIS AWANG & DE CHAVEZ, C.G. 1993. Kesan pemangkasan akar dan penyiraman terkawal ke atas pertumbuhan, ketahanan kepada kemarau dan kualiti anak bogel *Acacia mangium*. Kemungkinan penyesuaian dan pengerasan anak bogel *Acacia mangium* dengan memangkas akar dan mengawal penyiraman telah di selidiki. Anak benih berumur 10 minggu dibatas terbuka dikenakan gabungan rawatan tiga regim pemangkasan (tidak dicantas, dicantas 2 minggu sekali dan dicantas setiap bulan) dan 2 regim penyiraman (sekali tiap tiga dan enam hari). Anak benih yang ditabung dan disiram setiap hari digunakan sebagai kawalan. Dua belas minggu kemudian, anak benih tersebut di taksir untuk pengeluaran bahan kering, nisbah diameter/ketinggian, hubungan air dan kemandirian. Pemangkasan

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akar dan penyiraman terkawal mempunyai kesan yang bererti kepada kebanyakan parameter pertimbuhan. Kemandirian yang baik disekutukan dengan nisbah akar/ pucuk, nisbah diameter/ketinggian, kemampuan pertumbuhan akar yang tinggi dan ekonomi air yang cukup. Kemandirian yang baik diserap pada anak benih yang disiram setiap enam hari dan dicantas samada setiap bulan atau setiap 2 minggu sekali. Anak benih kawalan yang mempunyai perkembangan pucuk yang baik tetapi kemampuan pertumbuhan akar yang rendah dan ekonomi air yang kurang menunjukkan kadar kemandirian yang rendah. Anak benih bogel tidak dicantas yang disiram setiap tiga hari berkemandirian yang rendah berbanding dengan anak benih tidak dicantas yang disiram setiap 6 hari. Anak benih yang akan dicantas setiap bulan memberi keputusan kemandirian yang lebih baik sedikit dari anak benih yang dicantas setiap dua minggu, menunjukkan penambahan kekerapan tidak semestinya menambahkan kemandirian. Gabungan pemangkasan akar setiap bulan dan penyiraman setiap 6 hari adalah disyorkan.

Introduction

Acacia mangium has been extensively grown in forest plantations in Malaysia. The seedlings are raised in containers and planted out in the field ball-rooted with the roots intact to ensure high survival rates. However, this practice is associated with high nursery and establishment costs. Seedling production alone accounts for almost 10% of the total cost incurred over an establishment period of four years. The use of bare-rooted seedlings would help to reduce such cost and those associated with seedling transportation and planting (Evans 1982).

Hitherto, the only attempt reported on the use of bare-rooted seedlings for planting of *A. mangium* is at the ASEAN New Zealand Afforestation Project in the Philippines (Batara & Inglis 1986). However, success in terms of survival and growth performance was limited to better sites. It is therefore important that the planting stock produced is of a quality which reflects the morphological and physiological preparedness of the seedlings to cope with more difficult sites.

Such seedling quality can be obtained through manipulation of growing conditions in the nursery. Root-wrenching and restricted watering have been reported to be effective pretreatments for a number of other species (Rook 1971, 1972, Kamis Awang 1973, Sandi 1982). This study was aimed at testing the effectiveness of various regimes of root wrenching and restricted watering in producing bare-root *A. mangium* seedlings that can withstand the stress after being outplanted.

Materials and methods

Plant material

A.mangium seeds, collected from the Universiti Pertanian Malaysia arboretum, were germinated in a sandbox. Three weeks later, the seedlings were transplanted into open beds of 1.2 x 12 *m* at a spacing of 15 x 15 *cm*. The medium of these beds consisted of an equal mixture of sieved river sand and soil. Some other seedlings to be used as control were at the same time transplanted into polythene bags (15 x 23 *cm* measured flat) using the same medium. No special pretreatment was applied to the medium. The seedlings were watered daily and weeded regularly to maintain optimum growth. The beds were covered with transparent plastic sheets to keep out the rain. To promote growth, NPK (15:15:15) blue (a commonly available fertilizer) was added three weeks after transplanting.

Experimental design

A 3x2 factorial with a control was the experimental design used. The two factors were root wrenching frequency and watering regime. Together, seven different treatments, each involving more than 60 seedlings, were tested. They were:

CON - control, *i.e.* potted seedlings with watering once daily and no wrenching;

WOD3 - no wrenching with watering every three days;

WOD6 - no wrenching with watering every six days;

W2D3 - fortnightly wrenching with watering every three days;

W2D6 - fortnightly wrenching with watering every six days;

W4D3 - monthly wrenching with watering every three days;

W4D6 - monthly wrenching with watering every six days.

The transplanting beds were initially partitioned into seven equal compartments and the treatments were randomly assigned to these compartments. Root wrenching and restricted watering were imposed when the seedlings were 10 and 14 weeks old respectively. Wrenching was done with a sharp blade dragged along the beds 13 *cm* beneath the surface.

Data determination and analysis

When the seedlings were 22 weeks old, the age when they are normally outplanted (Kamis Awang 1973), the following measurements were made:

(i) Ten randomly selected seedlings from each treatment were measured for root collar diameter and height. They were then harvested for the determination of shoot, root and total dry weights as well as root/shoot ratio.

(ii) For the comparison of transpiration rates, 10 seedlings from each treatment were lifted from the beds and replanted into plastic pots of 18 *cm* diameter. Five of the seedlings were maintained at about field capacity by giving adequate watering daily. The other remaining five seedlings were initially watered to about field capacity and then left unwatered. For both groups of seedlings, daily transpiration rates were measured using a steady state porometer. Three mature leaves for each seedling taken from the top, middle and lower section of the plant were used. Readings were taken in the morning, afternoon and in the evening. The daily rate was calculated from the means of three leaves.

(iii) To establish desorption curves relating leaf relative turgidity and xylem water potential, 15 seedlings from each treatment were replanted in polybags. The seedlings were watered thoroughly once and then allowed to dry over two weeks. A seedling was harvested daily for leaf relative turgidity and xylem water potential measurements. Relative turgidity was determined based on Barrs and Weatherlay's (1962) method using leaf discs. The xylem water potential was measured with a pressure 'bomb'.

(iv) To test for survival capacity, 10 seedlings from each treatment were first transplanted into pots, watered thoroughly and then allowed to dry in full sunlight. Survival count was recorded daily.

(v) Root growth capacity was determined through the change of root volume measured using the displacement technique described by Burdett (1979). For each treatment, 10 seedlings were carefully lifted and their root systems washed. After determining their root volume, the seedlings were replanted into polybags (20 x 28 *cm*) and allowed to grow under a nursery condition with about 40% shading for four weeks. Their root volume was then reassessed, and the percentage change over the initial value was calculated.

Data on height, diameter, root, shoot and total dry weights, root/shoot ratio, diameter/height ratio and root growth capacity were subjected to a two-way analysis of variance to determine the effect of root wrenching, controlled watering and their interaction. Duncan's multiple range test was used to assess the significance of differences between treatment means. For the relationship between leaf relative turgidity and xylem water potential, the measurement data were analysed by simple linear regression.

Results

Growth performance

Anova results showed that root wrenching affected significantly ($p < 0.05$) all of the growth parameters except for the diameter and root growth capacity (Table 1). The root growth capacity was significantly influenced by controlled watering only. Root wrenching x watering interaction was not significant. Table 2 presents the results of Duncan's multiple range test done on the seven treatment means of various growth parameters. The means sharing the same letter (s) are not significantly different at 5% probability level.

All wrenched seedlings were significantly lower in shoot dry weight when compared to the unwrenched and potted seedlings (Table 2). Lowest shoot

Table 1. Summarised results of ANOVA on the effects of root wrenching and controlled watering on the growth of *A.mangium*

Growth parameters	Root wrenching	Controlled watering	Interaction
Root dry weight	*	ns	ns
Shoot dry weight	**	ns	ns
Total dry weight	**	ns	ns
Root/shoot ratio	**	ns	ns
Height	*	ns	ns
Diameter	ns	ns	ns
Diameter/height ratio	**	ns	ns
Root growth capacity	ns	*	ns

Significant level: * $p < 0.05$; ** $p < 0.01$; ns not significant.

development was recorded in seedlings wrenched fortnightly and watered every six days (W2D6). Wrenching frequency did not significantly alter shoot dry weight. The shoot development in unwrenched seedlings was comparable to the control seedlings. Restricted watering also resulted in less shoot development with low shoot weights in treatments with 6-day watering intervals. The unwrenched seedlings (WOD3 and WOD6) were characterised by significantly lower dry root biomass in comparison to wrenched seedlings (Table 2). Wrenching encouraged root development presumably through the elongation of lateral roots and increase in tertiary root development. Increased severity of wrenching and drought appeared to depress root production. In general, root production in the control plants was significantly greater than in all other treatments.

The overall growth of the seedlings in terms of total dry weight production was affected by root wrenching and controlled watering in a similar way as in shoot production (Table 2). Growth was largest for control and for unwrenched seedlings. There was a general decrease in total dry weight with the increase in wrenching frequency and controlled watering. On the other hand, the root/shoot ratio followed the pattern of root production, with significantly higher values for wrenched seedlings. Reduced watering resulted in higher root/shoot ratios. Unwrenched seedlings as well as control seedlings had lower root/shoot ratio than wrenched seedlings.

However, as indicated in Table 2, the root growth capacity was distinctly low for control and unwrenched seedlings. All others were significantly higher. Seedlings subjected to watering every six days exhibited a higher root growth capacity than less severely conditioned seedlings.

In general, root wrenching reduced height growth but the values for wrenched seedlings with watering every three days (W2D3 and W4D3) were not significantly

Table 2. Effect of root wrenching and controlled watering on the growth of *A. mangium.* Means having the same letters are not significantly different at 5% level according to Duncan's multiple range test

Treatment	Root dry weight(*g*)	Shoot dry weight(g)	Total dry weight(*g*)	Root/shoot ratio	Height (*cm*)	Diameter (*cm*)	Diameter/ height ratio	Root growth capacity (%)
CON	2.50	8.83 a	11.32	0.28 a	55.7 a	5.2 a	1.06 a	95.4 a
WOD3	0.76 a	7.63 a	8.39 a	0.08 b	39.8 a	4.2 a	1.07 ab	91.6 a
WOD6	0.85 ab	7.48 a	8.36 ab	0.11 b	40.2 a	4.6 a	1.17 ab	145.5 b
W2D3	1.45 bc	4.41 b	5.86 ab	0.33 ac	28.5 ab	3.8 a	1.33 bc	150.6 b
W2D6	1.48 bc	4.19 b	5.69 b	0.35 ac	23.0 b	3.4 a	1.47 c	166.3 b
W4D3	1.63 c	4.93 b	6.55 ab	0.32 ac	28.8 ab	4.0 a	1.41 c	140.4 b
W4D6	1.51 bc	4.20 b	5.69 ab	0.41 c	25.2 b	3.7 a	1.53 c	155.4 b

different from those of unwrenched seedlings (Table 2). Control plants and unwrenched seedlings achieved bigger diameters than wrenched seedlings, but differences among treatment means were not significant. However, seedling sturdiness expressed by the diameter/height ratio was significantly higher for wrenched seedlings (Table 2). The highest value was obtained in treatment with monthly wrenching and six-day watering (W4D6). There is no indication that increase of wrenching frequency improved the sturdiness. However, decrease of watering frequency seems to produce sturdier plants.

Water relations

The transpiration rate and desorption curve relating leaf relative turgidity and xylem water potential were determined. The transpiration rates of seedlings transplanted in soil maintained at field capacity are shown in Figure 1. In general, control seedlings had the highest transpiration rate throughout the duration of the experiment. Unwrenched seedlings also showed relatively high rates. Transpiration rate was markedly affected by the preconditioning treatments. Generally, the rate was lower with lower watering and higher wrenching frequency.

Similar differences were observed for transpiration rates of seedlings transplanted in soil initially watered to field capacity and later left unwatered (Figure 2). Generally, all treatments showed a decrease in transpiration rates as soil became drier. The control seedlings which started initially at the highest rate showed a drastic decrease after the fifth day of transplanting. They ended at a very low rate on the sixteenth day. By contrast the preconditioned seedlings started with lower transpiration rates which declined slowly until the eight day and remained fairly constant thereafter, especially for the wrenched seedlings. Unwrenched seedlings, particularly those watered every three days (WOD3), showed a substantial decrease in transpiration rates from the start to the final day of observation.

Figure 3 shows the relationship of leaf relative turgidity and the xylem water potential. Distinct differences can be seen between the unconditioned control seedlings and preconditioned seedlings. At any xylem water potential, the control plants had the lowest moisture content. Higher moisture retention was obtained in seedlings subjected to more severe draughting or wrenching. This suggests that the preconditioned seedlings had improved water relations which could prevent rapid dehydration in dry conditions. The lower transpiration rates of these seedlings have already been noted.

Survival

The daily survival count of seedlings, left unwatered after transplanted into polybags and initial watering, is shown in Table 3. Wrenched seedlings performed better than unwrenched seedlings. Highest mortality was recorded for control seedlings and unwrenched seedlings watered every three days (WOD3) after 10

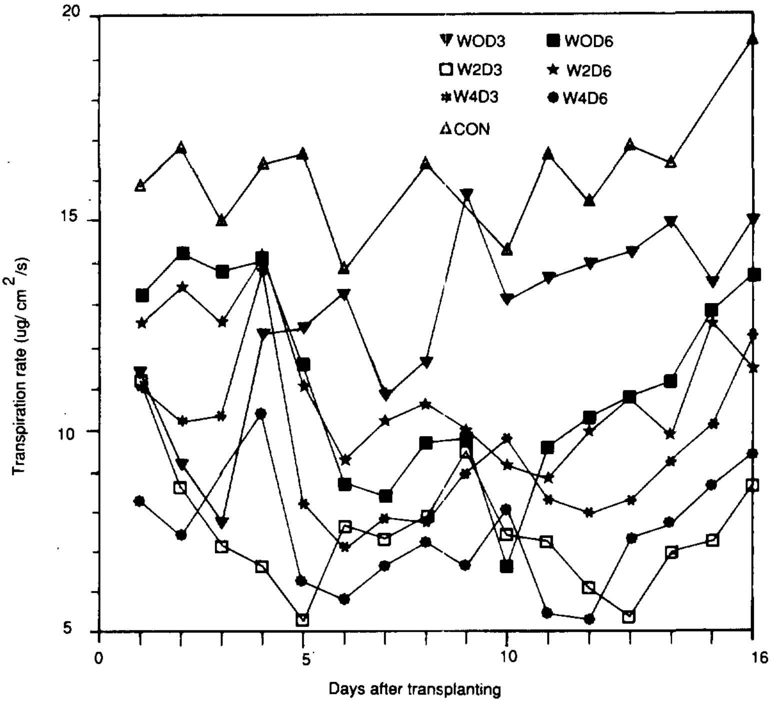

Figure 1. Daily transpiration rates of seedlings transplanted in soil maintained at field capacity

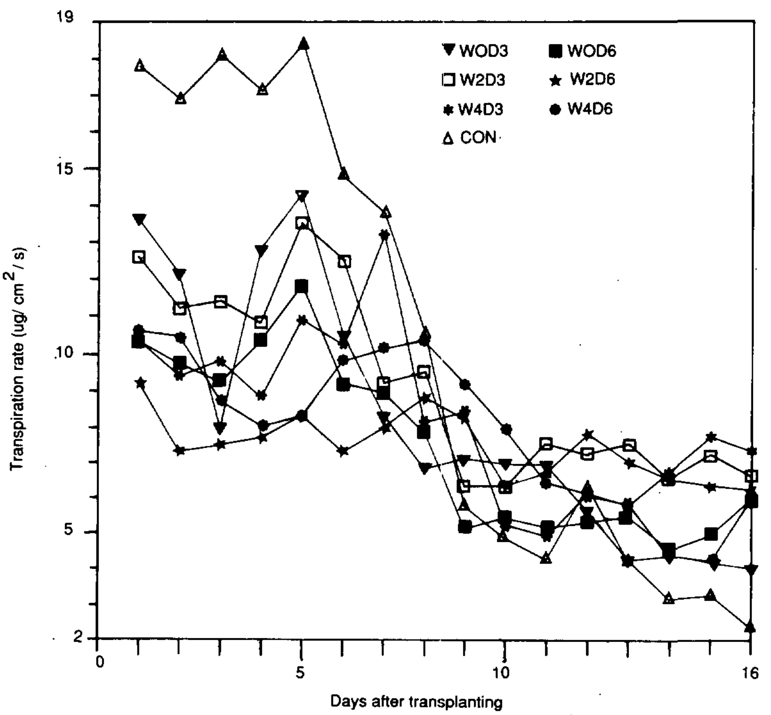

Figure 2. Daily transpiration rates of seedlings transplanted in soil initially watered to field capacity and then left to dry

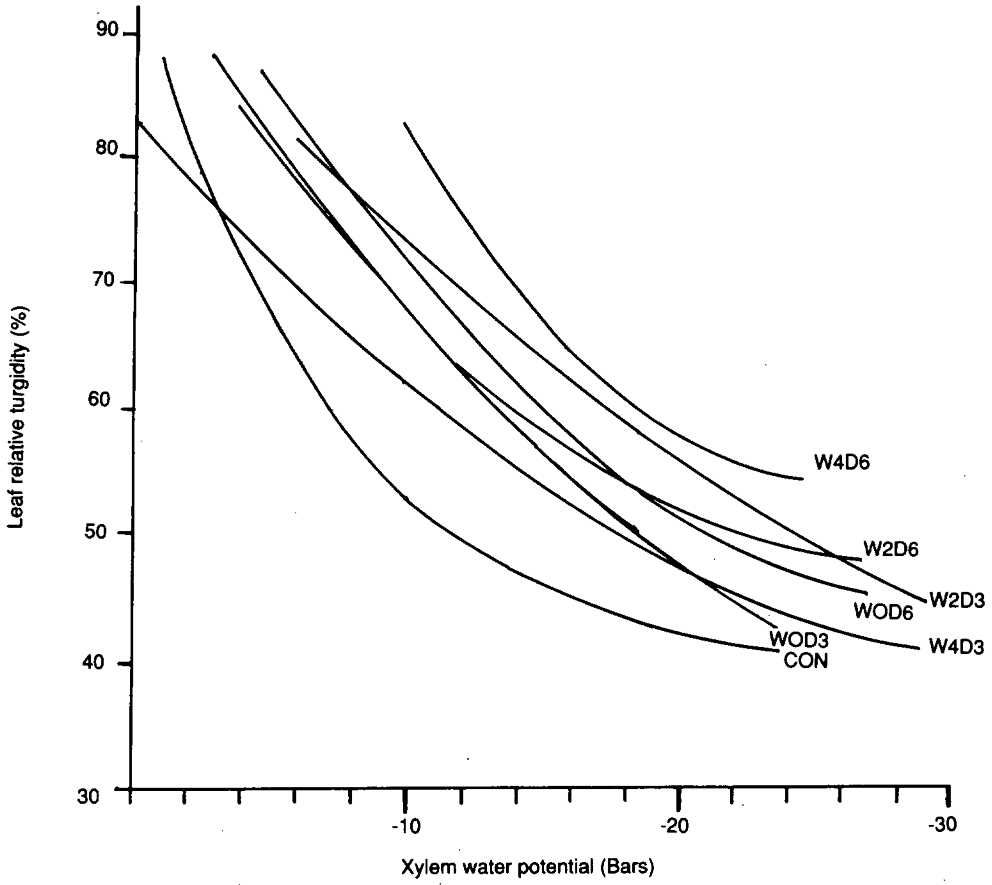

Figure 3. The leaf relative turgidity and xylem water potential of the various treatments

days without watering. On day 10, 80% of the transplanted seedlings watered every six days (W4D6, WOD6 and W2D6) survived. After 14 days all unwrenched seedlings watered every three days (WOD3) had died. The control seedlings followed two days later. Sixty percent of the seedlings of treatment W4D6, 50% of treatment W2D6, and 30% of WOD6 were still alive. All these seedlings had been raised under 6-day controlled watering regime and had shown superior survival rates under drought. Two seedlings of the fortnightly wrenched seedlings (W2D6) persisted until the ninteenth day.

Discussion

Growth and survival

Root wrenching affects plant growth by disrupting the normal water and nutrient intake. Water and nutrient intake is impeded which in turn retards growth. This study shows that shoot and height growth were more affected than root or diameter growth. Similar results have been reported for *Pinus radiata*

Table 3. Daily survival count of seedlings transplanted in soil initially watered to field capacity and then allowed to dry

Days after transplanting	Treatment						
	CON	WOD3	W2D3	W4D3	WOD6	W2D6	W4D6
1	10	10	10	10	10	10	10
2	10	8	10	10	10	10	10
3	10	8	8	10	10	10	10
4	10	8	8	10	9	9	10
5	10	8	8	10	9	9	9
6	10	7	7	8	9	9	9
7	10	7	6	8	9	9	9
8	9	7	5	7	9	9	9
9	7	5	5	7	8	9	8
10	6	5	5	6	8	8	8
11	4	3	4	5	5	8	7
12	3	2	4	5	5	6	7
13	3	2	2	3	3	5	7
14	1	-	2	3	3	5	6
15	1	-	2	2	1	3	5
16	-	-	2	2	1	3	5
17	-	-	-	1	-	3	4
18	-	-	-	1	-	-	2
19	-	-	-	-	-	-	2

(Rook 1971, Benson & Sheperd 1976, van den Driessche 1983), *P. caribaea* (Nor Akhiruddin 1982, Sandi 1982) and *Pseudotsuga menziesii* (Duryea & Lavender 1982, van den Driessche 1983).

According to Tanaka *et al.* (1976), wrenched seedlings of *P. menziesii* showed higher root dry weights. *A. mangium* shows a similar trend. Following the severance of the tap root, the lateral root probably developed more in order to increase the absorptive capacity (Stupendick 1977). In addition, the stimulation of root growth is probably a result of improved soil aeration during root wrenching operations (Eis & Long 1972).

Seedlings survival in the field is highly correlated to root growth capacity (Burdett 1979, Sutton 1980). Planting stock with high root growth capacity is likely to show low mortality after planted out. In the present study, this correlation cannot be positively confirmed. The nursery survival test was done to simulate field planting under dry spells. Although this may not quite represent actual field conditions, the results indicated positive correlation between the root growth capacity and survival. However, it is still unclear as to what degree or under what circumstances the correlation occurs (Burdett 1979). This needs to be further investigated.

Seedling quality

Both morphological and physiological characteristics have been used as indices of seedling quality (Stupendick 1977). Diameter:height and root:shoot ratios are two commonly used morphological indices. The former reflects seedling sturdiness and hardiness (Rook 1971), while the latter reflects the balance between the absorptive surface and the evaporative surface. Root wrenching and controlled watering have been reported to increase the diameter:height ratio in *Pinus radiata* and *P.caribaea* (Rook 1971, Nor Akhiruddin 1982, Sandi 1982), and the root:shoot ratio in *P. caribaea* (Sandi 1982). This study showed that better quality seedlings with both ratios improved could also be obtained in a similar way for *A. mangium.*

Drought resistance

Survival of planting stocks in the field depends heavily on their ability to regulate their internal water balance under stress conditions. In dry soil conditions, failure of newly planted stocks to retain water and extend new roots into the surrounding soil may prove fatal (Coppock 1986). According to Hennessey and Dougherty (1984), seedlings subjected to water related stress such as root wrenching and restricted watering may have undergone soil osmotic adjustments. Solutes accumulate in sufficient quantity to change the osmotic potential. This creates the driving force that brings water from the soil to the plant or retain its water in the cells. This adjustment enhances tolerance to dehydration and also allows the extension of roots into the surrounding soil for water. The preconditioned seedlings in this study might have made this adjustment.

Relative turgidity of leaf in *A. mangium* was generally lower in control and unwrenched seedlings at any plant xylem water potential. This suggests that the treatments had altered the ability of the seedlings to retain shoot moisture under stress conditions. But species differ in their capacity to adapt. For example, Sandi (1982) found that severe water restriction regimes improves seedling water control more effectively than combined treatments of water restriction and root wrenching. Williams (1974) observed that container-raised *P. caribaea* have higher relative leaf water content than wrenched bare-rooted stocks in dry soil conditions. In this study, however, seedlings wrenched monthly and subjected to watering every six days showed best water retention. Control seedlings on the other hand, were less efficient in water economy (Figure 3).

Root wrenching and water restriction create water stress on plants, resulting in stomatal closure and reduction in transpiration rates (Stupendick & Shepherd 1980). These changes affect the photosynthetic processes resulting in reduced translocation of photosyntate to the roots. Rawat *et al.* (1985) found that in restricted soil moisture conditions the transpiration rate in plants was reduced. The results with *A.mangium* concur with these findings.

When moisture was adequate, the transpiration rates of control seedlings were generally higher than those of bare-rooted seedlings. Under drought stress, the control seedlings experienced a sharp decline in transpiration rate after a few days of transplanting. They show low drought tolerance by losing water rapidly through transpiration and approach wilting conditions sooner than bare-rooted seedlings. Such a drastic decline in transpiration rates has also been reported for tubed *P. caribaea* following transplanting in soils under drought conditions (Williams 1974). On the other hand, seedlings that had undergone severe conditionings were able to economise on their internal water balance and hence survived longer.

Conclusion

To condition and harden bare-rooted seedlings, a monthly root wrenching regime is recommended. Watering every six days is preferred to a three-day watering regime. Field testing of the seedlings is needed to confirm the findings.

Acknowledgements

We thank Lim Meng Tsai, David Taylor and Mohd. Basri Hamzah for their comments on the initial draft of the manuscript.

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