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FIELD GROWN *ACACIA MANGIUM* : HOW INTENSIVE IS ROOT GROWTH?

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WAN RASIDAH, K., AZIZOL, A.K., VAN CLEEMPUT, O. & ZAHARAH, A.R. 1998. Field grown *Acacia mangium* : How intensive is root growth? Under rainfed conditions, root development of trees can be very unpredictable and variable, depending on the amount and distribution of rainfall received. This becomes more critical when the rainfall is seasonal and the soil has a high clay content. Our investigation dealt with the root development of *Acacia mangium* established as plantation forest on a soil with heavy clay texture in Kemasul Forest Reserve, Malaysia. The distribution of active roots was measured at 9- and 21-month-old plantations using the radioactive ^{32}P injection method. Growth at different distances from the tree base and at different soil depths was studied. After nine months of field planting, we found that roots were mostly concentrated at the surface within 1000 mm distance from the tree base. At one year after the first measurement, roots were traced as far as 6400 mm away. A large part of these roots, however, were detected within 3700 mm distance in the upper 300 mm soil. At this stage, roots still did not go deeper than 450 mm depth, probably due to the high clay content at lower depth and low pH. This rapid root growth indicates that below-ground competition can be very intense if this species is established as a mixed-species plantation.

Key words: Acid soil - root activity - heavy clay soil - foliar analysis - forest plantation - radioactive ^{32}P

WAN RASIDAH, K., AZIZOL, A.K., VAN CLEEMPUT, O. & ZAHARAH, A.R. 1998. Tanaman ladang *Acacia mangium* : Berapakah kadar pertumbuhan akar? Dalam keadaan di mana pokok bergantung kepada hujan sebagai sumber air, pertumbuhan akar selalunya tidak sekata dan sukar diramal. Biasanya ia bergantung kepada jumlah dan taburan hujan. Pertumbuhan akan menjadi lebih tidak sekata jika hujan yang diterima bermusim dan tanah mempunyai kandungan lempung yang tinggi. Kajian telah dijalankan untuk mengkaji perkembangan akar pokok *Acacia mangium* yang ditanam untuk penubuhan ladang di Hutan Simpan Kemasul, Malaysia. Tekstur tanah adalah daripada kumpulan lempung tinggi. Taburan akar aktif diukur pada umur tanaman 9- dan 21-bulan menggunakan kaedah suntikan radioaktif ^{32}P. Pengukuran dijalankan pada beberapa jarak berbeza daripada pokok dan juga pada beberapa kedalaman tanah. Dalam masa sembilan bulan selepas penanaman, kami mendapati pertumbuhan akar tertumpu di kawasan permukaan tanah di dalam jarak 1000 mm daripada pokok. Setahun selepas pengukuran pertama dilakukan, akar dapat dikesan sehingga ke jarak 6400 mm. Bagaimanapun, pertumbuhan akar yang pesat adalah di dalam jarak 3700 mm pada kedalaman di antara 0-300 mm. Akar *A. mangium* masih belum melepasi kedalaman 450 mm kemungkinan disebabkan oleh kandungan lempung yang tinggi dan keadaan tanah yang masam. Pertumbuhan akar yang pesat ini memberikan gambaran bahawa persaingan dalam tanah boleh menjadi kritikal sekiranya spesies ini ditanam bersama spesies lain dalam satu kawasan.

Introduction

Commercial forest planting in Malaysia is becoming more important because of the limited supply of high quality timber and the increase in timber price as a result of supply shortages and improved wood based technology. Another reason is the low manpower to area ratio of 1:50 ha for forest as compared to 1:8.6 ha for oil palm and 1:3.5 ha for rubber (Malaysian Timber Council 1995). *Acacia mangium* Willd., a fast growing tree, is among the species planted commercially as plantation forest. Fast growing tree species usually develop an intensive rooting system, particularly in a low fertility soil. Since root activity is one of the important aspects in plant nutrition studies, we initiated this research in September 1992 to study the extent of root development of an *A. mangium* stand established in December 1991. Another measurement was followed one year after the first measurement.

Several methods have been introduced to measure root development of field grown plants. In some reported studies, the direct and tedious method of excavating the roots has been used (Ong *et al.* 1992, Van Noordwijk & Dommergues 1991). Ben-Asher *et al.* (1994a, b) adopted an indirect approach by measuring surface CO_2 flux and assessed its correlation with the major root characteristics such as length, area, mass and number. In a mixed hardwood forest, root activity accounts for nearly two thirds of the soil respiration (Bowden *et al.* 1993). Other reported studies used radiotracer techniques (Kurien *et al.* 1992, Mahisarakul *et al.* 1994). In this approach, radioactive ^{32}P is applied at selected distances and its movement is traced in the leaves of the plant studied. This tracer technique was used in our measurement because of easy sampling and the availability of materials and analytical facilities.

Materials and methods

Site characteristics

The plantation area where this study took place can be described as homogeneously heterogeneous. It was planted with *A. mangium* as monoculture in December 1991.

However, other pioneer species such as mahang (*Macaranga* spp.), senduduk (*Melastoma malabathrium*), a few grass species and many small plants have been occupying the interspaces and growing vigorously. Species distribution was scattered. The area received about 1500 mm of rain in 1992 and 2250 mm in 1993. The distribution, however, was seasonal with the highest peak around May and November. In 1992, the lowest amount was 19 mm, recorded in June and the highest was 286 mm, recorded in November. A minor shift was noted in 1993, with the lowest value of 47 mm, recorded in February, and the highest was received in October with 350 mm. The soil was of low fertility, highly weathered with a high clay content. At 1000 mm depth, clay represented more than 50 % of the soil texture. Bulk density (BD) of the soil increased with depth while pH decreased: 0-50 mm depth - BD 0.86 g cm^{-3}, pH 4.60; 50-150 mm depth - BD 1.32 g cm^{-3}, pH 4.45; 150-300 mm depth - BD 1.42 g cm^{-3}, pH 4.47; 300-450 mm depth - BD 1.33 g cm^{-3}, pH 4.42.

Field experimental layout

Measurements were carried out at two stand ages: 9 months old (September 1992) and 21 months old (September 1993). At both ages, the layout was a completely randomised design with five replicates.

At stand age of 9 months, ^{32}P was injected in the soil in a circle at three distances and two depths from the tree base. The distances chosen were 500, 1000 and 1500 mm, and the depths were 50 and 300 mm. In total, 30 trees were treated as each plot consisted of only one tree (3 distances × 2 depths × 5 replicates). A similar number of injection holes was used for the tree distances. Technical problems related to the preparation of injection holes at 300 mm depth made a higher number of application points very difficult. Big holes would damage the rooting system and the high clay content at this soil depth prevented easy penetration by a small diameter auger. Each tree received 37×10^6 Bq (1 mCi) ^{32}P with KH_2PO_4 as carrier. Approximately four weeks after the ^{32}P application, foliar samples were collected at every fourth leaf counted from the shoot tip of the selected trees.

A slightly different layout was used at the 21-month-old stand age. Only one tree (number 1) was treated with ^{32}P at a rate of 74×10^6 Bq (2 mCi) with KH_2PO_4 as carrier. The distance was 1000 mm from the tree base. The depth remained the same as for the 9 -month-old measurement. After four weeks, a number of trees were sampled at different distances from the treated tree. A detailed layout is presented in Figure 1. Foliar collection was restricted to every fifth leaf. The difference in the sampling method between the two ages was due to the biomass availability. Whenever necessary, subsampling was carried out.

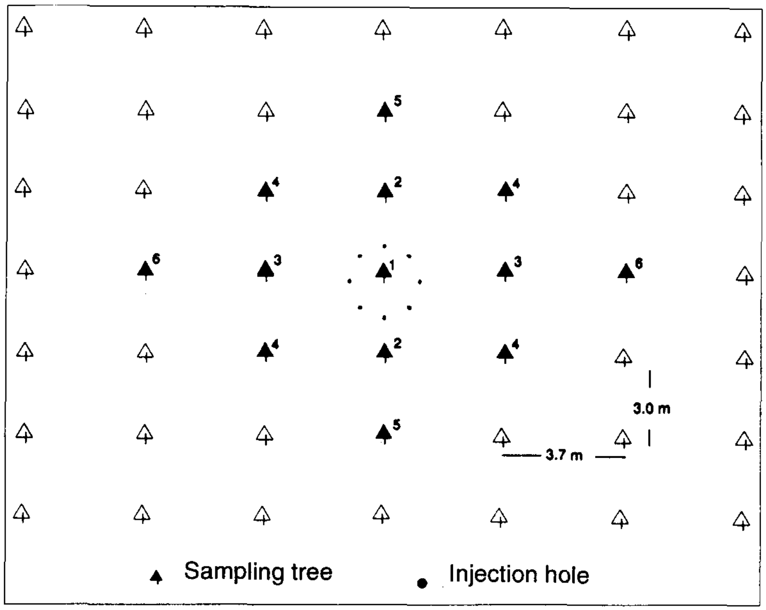

Figure 1. Experimental layout for the root activity study of the 21-month-old plantation

Foliar analysis

Samples were brought back to the laboratory, oven-dried at 70 °C, crushed, accurately weighed (5 g) and ashed first at 200 °C for 2 h and then for 4 h at 500°C. The ash was treated with 20 ml 2N HCl and filtered. The collected filtrate was counted for radioactivity using liquid scintillation counter with pico aqua as scintillation cocktail.

Results were statistically analysed using the General Linear Model procedure via the SAS program (SAS Institute 1985). The $\log_{10}$ transformed data were used to satisfy the value of coefficient of variation. These values were more than eighty percent when analysed with the actual counting data. The log transformation is allowed in statistical analysis provided the same scale is applied to all observations (Gomez & Gomez 1984).

Results

The intensity of active roots at a particular distance and depth is indicated by the number of counts obtained in the plant material. These data are presented in Figures 2 and 3. A high variability was observed with these experiments as shown by the value of standard error. Regardless of the age, the activity was always highest for the application nearest to the tree base. In Figure 2, differences between the application at two depths were not very pronounced. Only at 1000 mm distance the difference was noted. The results show that the active roots were somewhat more concentrated towards the surface of the soil. Nevertheless, it was clear that already after nine months of growth, the roots reached a distance of 1500 mm.

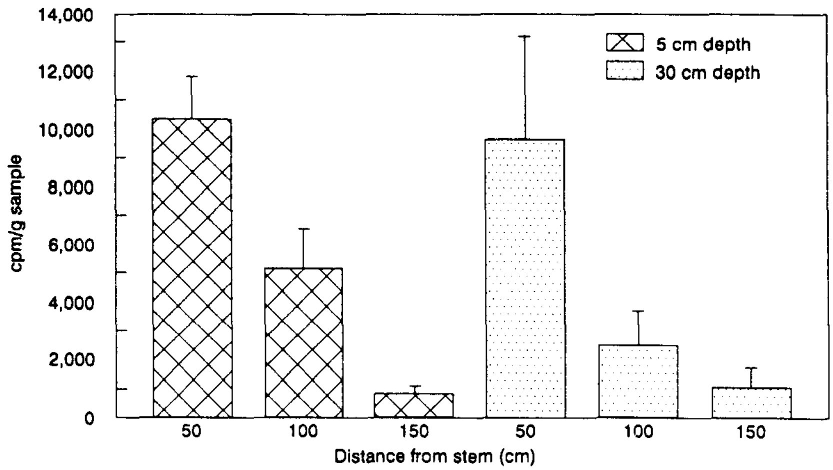

Figure 2. Activity in 9-month-old *Acacia mangium* at different distances from the tree base, upon ^{32}P injection at 5 and 30 cm depths. Vertical bars represent one standard error.

In contrast to the experiment at the age of 9 months, active roots of *A. mangium* after 21 months of field planting were more established at 300 mm depth (Figure 3). Differences between depth, however, were not important at higher distances. A very important root development was observed during one year of growth (from the age of 9 to 21 months) where active roots were detected as far as 6.4 m from the tree base.

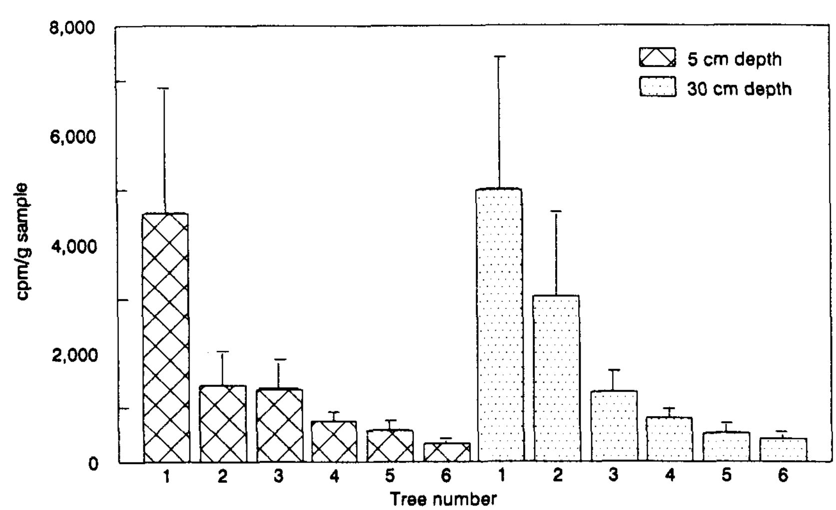

Figure 3. Activity in 21-month-old *Acacia mangium* at different distances from the application area, upon ^{32}P injection at 5 and 30 cm depths. Vertical bars represent one standard error.

Analysis of variance for the 9-month-old *A. mangium* did not show any interaction between distance and depth of application (Table 1). There was, however, a highly significant difference with the distance of application. A mean comparison was carried out using the Duncan multiple range test (Table 2). There was a significant reduction in ^{32}P uptake when it was applied at 1500 mm distance and 50 mm depth. When application was performed at 300 mm depth, a significant increase in uptake was obtained only with the treatment at 500 mm distance from the tree base.

Table 1. Statistical values obtained by the general linear model procedure for different distances and depths of ^{32}P application at 9-month-old *Acacia mangium* stand, based on $\log_{10}$ transformed data

Source	DF	Sum of squares		F value		Pr > F	
		Type I	Type III	Type I	Type III	Type I	Type III
Distance	2	8.864531	8.864531	18.48	18.48	.0001	.0001
Depth	1	0.513490	0.537714	2.14	2.24	.1575	.1485
Distance × depth	2	0.125824	0.125824	0.26	0.26	.7716	.7716

DF - degree of freedom.

Table 2. Mean separation analysis for different distances at 9-month-old *Acacia mangium* stand based on the Duncan multiple range test

Depth (mm)	Distance (cm)		
	50	100	150
50	4.705 a	4.326 a	3.513 b
300	4.613 a	3.938 ab	3.158 b

Means sharing the same letter across the row are not significantly different at 5 % probability level.

A similar pattern as for the 9-month-old stand was obtained when the analysis of variance was performed on the experiment with the 21-month-old trees. There was no interaction between the distance and depth, but a highly significant difference was obtained within the distance (Table 3). Further analysis using the Duncan multiple range test showed significant differences in uptake only between locations 1 and 6 at 50 mm depth. At 300 mm depth, however, distances 1, 2 and 3 showed no difference in uptake, but they were significantly different from distance 6.

Table 3. Statistical values obtained by the general linear model procedure for different distances and depths of ^{32}P application at 21-month-old stand based on log_{10} transformed data

Source	DF	Sum of squares		F value		Pr > F	
		Type I	Type III	Type I	Type III	Type I	Type III
Distance	2	5.93367281	5.98718731	7.01	7.08	.0001	.0001
Depth	1	0.17269357	0.16928901	1.02	1.00	.3148	.3196
Distance x depth	2	0.16380905	0.16380905	0.19	0.19	.9643	.9643

DF - degree of freedom.

Table 4. Mean separation analysis for different distances at 21-month-old *Acacia mangium* stand based on the Duncan multiple range test

Depth (mm)	Tree number					
	1	2	3	4	5	6
50	3.202 a	2.918 ab	2.953 ab	2.655 b	2.675 b	2.499 b
300	3.376 a	3.125 ab	2.997 abc	2.741 bcd	2.650 cd	2.512 d

Means sharing the same letter(s) across the row are not significantly different at 5% probability level.

Discussion

Our observation (through root excavation) at three months after field planting showed that most of the roots were still within the polybag area (Wan Rasidah 1995). However, it was clear that after nine months of field planting, active roots had extended up to 1500 mm distance. A vigorous root development was observed closer to the tree base. Lateral root growth seems to be more important than the downward growth. Nevertheless, it is worth noting here that these results could not be interpreted as quantitative since a similar number of injection points was used for each distance. There will be a higher probability of root contact with ^{32}P for applications closer to the tree base.

By September 1993 (21 months after transplanting), *A. mangium* roots were more concentrated within 370 cm in the upper 30 cm layer, as shown by the number of counts. This was not surprising since a destructive sampling conducted for biomass analysis at stand age of 18 months showed that the downward movement of roots had reached 45 cm depth (Wan Rasidah 1995). At both depths at distance 6 (about 6.4 m from the application point), radioactivity counts, although significantly lower that at distance 1 (1.0 m), were much higher than the background counts. This shows that there was active root growth as far as 6.4 m away from the tree trunk. This rate of lateral root growth can be considered as rapid when compared with other fast growing trees. Root excavation carried out in Southern Sumatra, Indonesia, revealed that *Gliricidia sepium* roots can be traced at more than 6 m from its stem base. Although the tree age was not clearly mentioned, this hedgerow intercropping was more than 3 y old (Van Noordwijk & Dommergues 1991). In another development, Ong *et al.* (1992) reported that at Machakos, Kenya, roots of 5-y-old *Cassia siamea* trees extended up to 14 m from their stem base.

Root growth can be a function of environmental conditions and soil characteristics. A study carried out on a mature almond (*Prumus amdalus*) tree showed that favorable irrigation treatment enhanced larger and deeper root development. In our situation, the soil has high clay content, particularly at lower depth, and during the low rainfall period, the soil becomes very hard. This could have prevented deeper root development. At a semiarid region in the Sonoran Desert in southern California, Virginia (1986) reported that roots of a mature mesquite tree (*Prosopis glandulosa*) had reached more than 500 cm depth in a saline, clay loam soil that had several meters of dry soil above the water table. This reflected the strong influence of moisture on root development. Because the area where our experiment took place depends solely on the rainfall for water and receives no fertiliser, the intensive lateral root growth observed can be seen as a strategy for this tree to search for more water supply and nutrients.

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