GROWTH RESPONSE OF *ACACIA MANGIUM* PLANTATION TO N, P, K FERTILISATION IN KEMASUL AND KERLING, PENINSULAR MALAYSIA

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NIK MUHAMAD, M. & PAUDYAL, B. K. 1999. Growth response of *Acacia mangium* plantation to N, P, K fertilisation in Kemasul and Kerling, Peninsular Malaysia. Peninsular Malaysia launched the Compensatory Forest Plantation Project (CFPP) in 1982 to meet the increasing wood demand for domestic consumption. *Acacia mangium* is the main species planted. However, no comprehensive research has been performed on the nutrient requirements of this species. A NPK fertiliser study was, therefore, conducted on two sites, namely Kemasul in Pahang and Kerling in Selangor, with three- and five-year-old *A. mangium* stands. The experimental design used was a randomised complete block design (RCBD) with six treatments and five replicates. The treatments were: N0P0K0 (control), N0P1K1, N0P2K1, N1P1K1, N1P2K0 and N1P0K1 where P1 = 500 kg P_2O_5 ha^{-1}, P2 = 800 kg P_2O_5 ha^{-1}, N1 = 500 kg urea ha^{-1} and K1 = 100 kg K_2O ha^{-1}. The results showed that height and diameter were significantly increased by the combined effects of 800 kg P_2O_5 ha^{-1} and 100 kg K_2O ha^{-1}. The results also demonstrated that application of urea at the rate of 500 kg ha^{-1} might be necessary in Kemasul.

Key words: *Acacia mangium* - nutrients - plantation - fertiliser - growth

NIK MUHAMAD, M. & PAUDYAL, B. K. 1999. Tindak balas pertumbuhan ladang *Acacia mangium* terhadap pembajaan N, P, K di Kemasul dan Kerling, Semenanjung Malaysia. Semenanjung Malaysia melancarkan Projek Hutan Ladang Pampasan pada tahun 1982 bagi memenuhi pertambahan permintaan kayu untuk kegunaan tempatan. Spesies utama yang ditanam ialah *Acacia mangium.* Bagaimanapun, tiada penyelidikan menyeluruh dijalankan mengenai keperluan nutrien spesies ini. Oleh yang demikian, kajian baja NPK dijalankan di dua tapak, iaitu Kemasul di Pahang dan Kerling di Selangor dengan dirian *A.mangium* berumur tiga dan lima tahun. Reka bentuk percubaan yang digunakan ialah reka bentuk blok rawakan penuh (RCBD) dengan enam rawatan dan lima ulangan. Rawatan tersebut ialah: N0P0K0 (kawalan), N0P1K1, N0P2K1, N1P1K1, N1P2K0 dan N1P0K1 di mana P1= 500 kg P_2O_5 ha^{-1}, P2 = 800 kg P_2O_5 ha^{-1}, N1= 500 kg urea ha^{-1} dan K1 = 100 kg K_2O ha^{-1}. Keputusan menunjukkan ketinggian dan garis pusat bertambah dengan bererti dengan tindak balas bergabung bagi 800 kg P_2O_5 ha^{-1} dan 100 kg K_2O ha^{-1}. Keputusan juga menunjukkan bahawa penggunaan urea dengan kadar 500 kg ha^{-1} mungkin sesuai di Kemasul.

Introduction

Forest plantations in Malaysia began in 1957 with the planting of teak in the northern states of Perlis and Kedah. Later in the late 1960s and early 1970s, plantations of tropical pines, especially with *Pinus caribaea* var. *hondurensis,* was established for a planned pulp and paper industry to reduce the import of pulp and paper products. To offset the anticipated shortage of timber supply for domestic consumption, Malaysia has launched a Compensatory Forest Plantation Project (CFPP) since 1982 (Mohamad Darus & Lokman 1991). The project is to establish fast-growing forest plantations with a rotation of 15 years to produce general utility timber for the domestic market. The main species planted are *Acacia mangium, Gmelina arborea* and *Paraserianthes falcataria,* of which *A. mangium* represents more than 80% of the planted areas.

As most of the current forested areas are on low productivity land, there is a need to study the effects of fertiliser application on the growth of planted tree species on different soil types. Earlier studies on fertiliser requirements of Carribean pine (*P. caribaea*) seedlings by Platteborze *et al.* (1971) on Rengam soils, and by Carmean and Chew (1974) on Durian and Malacca soils, showed P to be the most important nutrient element for height growth of the seedlings. The work of Lim and Sundralingam (1974) on 6-y-old stands and the studies by Srivastava and Abang Naruddin (1979) on Durian soils and Manikam and Srivastava (1980) on Serdang soils further confirmed the above results. Wan Rasidah *et al.* (1988) also observed P to be important for height growth of *A. mangium* trees on Durian soils. Soil analysis on different soil types (Durian, Serdang soil series) planted with *P. caribaea* and *A. mangium* showed that available phosphorus levels were below 11.0 ppm (Srivastava & Abang Naruddin 1979, Manikam & Srivastava 1980, Wan Rasidah *et al.* 1988, Paudyal & Nik Muhamad 1992). Apart from the positive result of P application, interaction effects have also been reported. Anthony (1971) noted the beneficial effects of N, P, K on height, dry matter production and nutrient uptake of *P. caribaea* seedlings in potting mixtures. Zwierink (1984) reported that 228 kg ha^{-1} of N and 342 kg ha^{-1} of P significantly improved the growth of *G. arborea* seedlings whereas Kamis and Ismail (1986) recommended 600 kg ha^{-1} of N and P to boost initial height growth, leaf area and dry matter production. In the case of *A. mangium* plantations, except for some reports on soil and foliar analysis in the field (Paudyal & Nik Muhamad 1992, Amir Husni *et al.* 1993) and a fertilisation trial on Durian soil series by Wan Rasidah *et al.* (1988), no study has been reported on the nutritional aspects of this species under field conditions.

Acacia mangium (family Leguminosae, subfamily Mimosoidae) grows well up to 30 m in height. Mature trees are usually more than 15 m high, but on adverse sites they may not reach 10 m. Stem diameters up to 90 cm have been observed in natural forests of Queensland and Papua New Guinea (National Research Council 1983). It is a fairly light demander, coppices well, competes vigorously with *Imperata* grass and regenerates freely on disturbed sites. In Malaysia, this species has been widely planted. The growth is quite promising—MAI (mean annual increment) of

30 m^3 ha^{-1} y^{-1} has been reported in Sabah (Johari & Chin 1986). In Peninsular Malaysia, Paudyal and Nik Muhamad (1992) reported MAI (dbh) and MAI (ht) of 5-y-old *A. mangium* stand in Kemasul as 3.4 cm and 3.4 m respectively.

The objective of the study was to assess the growth response of *A. mangium* stands to different N, P, K fertiliser treatments.

Materials and methods

Experimental sites

Two sites were chosen for the field trials, namely Kemasul in Pahang and Kerling in Selangor states (Figure 1). These sites were chosen to represent comparatively nutrient rich (Kerling) and nutrient deficient (Kemasul) sites and to monitor the growth responses between them.

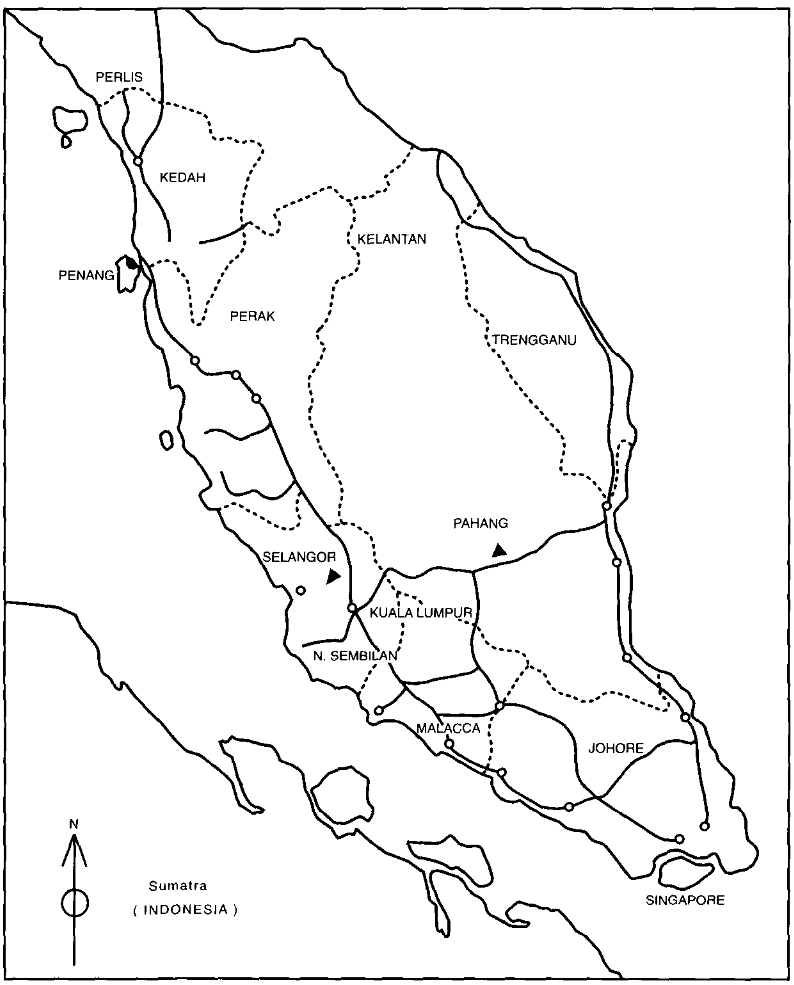

Figure 1. Map of Peninsular Malaysia showing the experimental sites

Kemasul plantation

Kemasul Forest Reserve is situated in the state of Pahang. It is 8 km south of the Mentakab-Karak/Kuala Lumpur highway at 3 ° 25' N and 102° 16' E. The average annual temperature varies from 21 to 32 °C. The mean annual precipitation is 1845 mm, rainfall occurring heavily during the months of August and November –December. The site is generally flat to slightly undulating with slopes ranging from 1 to 20%. The parent material is mainly of sedimentary and low grade metamorphic rocks. The soil is primarily of Durian-Batu Anam association (Ultisols-Typic Plinthudults) with black, sandy clay.

The trial plot was set up in Compartment No. 86A of the plantation established in 1986. The plantation was 5 y old at the beginning of the experiment. Trees were planted at a spacing of 3 × 3 m.

Kerling plantation

Kerling Forest Reserve is in the state of Selangor. The site is located 75 km from Kuala Lumpur adjacent to the Kuala Lumpur–Ipoh highway at 3° 45' N and 101° 47' E. The average annual temperature varies from 21 to 33 °C. The mean annual precipitation is 2581 mm, rainfall occurring heavily during the months of September–November and April–May. The area is generally undulating with slope gradient ranging from 1 to 20 %. The average elevation of the area is 61 m above sea-level. The parent material is mainly quartzite. The soils are primarily Serdang series (Ultisols-Typic Paleudults), reddish-brown in colour and sandy clay loam in nature.

The trial plot was set up in Compartment No. 88C of the plantation established in 1988. The plantation, also with tree spacing of 3 × 3 m, was 3.5-y-old at the start of the experiment. At one year of age, pruning to 50% of total height and brush cutting were done.

Soil and foliar sampling

Soil samples were taken randomly from five sampling points in each of the control plots. The samples were air dried at room temperature (22 °C) and sieved through 2.0 mm stainless steel sieve. Soil texture was determined by the pipette method. Soil pH was determined at 1:2.5 soil/water solution by a glass electrode pH-meter. Total N determination was done using the autoanalyser following the Kjeldahl's digestion procedure (Bremner 1965). Available P was measured in Bray's No. 1 solution and total organic carbon was determined by the Walkley and Black method (1934). Exchangeable K, Ca and Mg were determined by the Atomic Absorption Spectrophotometer adopting the NH_4OAC leaching method as outlined by Chapman (1965). The physical and chemical properties of soils sampled from the control plots of the two sites are given in Table 1.

Table 1. Physical and chemical properties of the soils on the two sites

Property	Depth	Kemasul	Kerling
Physical			
Clay (%)	A	40	20
	B	48	28
Silt (%)	A	13	6
	B	12	5
Fine sand (%)	A	31	33
	B	28	32
Coarse sand(%)	A	16	41
	B	12	35
Chemical			
pH	A	4.40	4.60
	B	4.00	4.10
Org. C (%)	A	1.13	1.40
	B	0.85	1.21
Total N (%)	A	0.06	0.08
	B	0.05	0.07
Av. P (ppm)	A	6.18	7.10
	B	6.05	7.02
Exch. K (meq/100g)	A	0.26	0.36
	B	0.20	0.24
Exc. Ca (meq/100g)	A	0.42	0.41
	B	0.28	0.27
Exch. Mg (meq/100g)	A	0.22	0.70
	B	0.08	0.58

Note: A— 0-20 cm, B—20-40 cm.

The foliar samples were taken from the upper one-third of the crown of all trees in each of the plots. Fully extended and sun exposed 12 leaves from each of the tree were collected for this purpose. The current year (young) foliage were sampled in the morning (0800–1100 h). The foliar samples were dried in a forced draft-oven at 75 °C for 36 to 72 h. Dried materials were ground in a stainless 'Fritch' pulverisette mill to pass through 1 mm round hole sieve. The foliar samples were analysed for total N, P, K, Ca and Mg by the wet digestion method (Parkinson & Allen 1975). Total N and P were simultaneously analysed on the original digest by the autoanalyser. Potassium, Ca and Mg were determined by atomic absorption spectrophotometer.

Experimental design and treatments

The experimental design was a randomised complete block design (RCBD) with six treatments and five replications. The single-tree plot technique suggested by Viro (1967) with 6 trees per replicate was used. There were 30 trees per treatment giving a total of 180 trees. Trees of almost the same height and vigour were selected. There were untreated buffer trees. At least a row of trees was used to separate plots within the block and two rows of trees to separate blocks. Each tree was marked for the identification.

The treatment combinations for N, P, K trial is given in Table 2. The treatments were N0P0K0, N0P1K1, N0P2K1, N1P1K1, N1P2K0 and N1P0K1 where N1 is 500 kg urea ha^{-1}, P1 is 500 kg P_2O_5 ha^{-1}, P2 is 800 kg P_2O_5 ha^{-1} and K1 is 100 kg K_2O ha^{-1}. The fertilisers applied were urea (46% N), triple superphosphate (48% P_2O_5) and muriate of potash (60% K2O). The elemental content of the fertilisers applied was as follows: N–230 kg ha^{-1}, P–208.9 kg ha^{-1} and K–49.8 kg ha^{-1}. In an earlier glasshouse study on *A. mangium* seedlings by Paudyal and Nik Muhamad (1996), it was found that 600 kg urea ha^{-1} and 800 kg P_2O_5 ha^{-1} boosted growth. Based on the glasshouse results, urea was given as 500 kg ha^{-1} only on the assumption that in older plantations nitrogen requirements may not be high as *A. mangium* itself is a legume species.

Before fertiliser application, each tree was clean-weeded at half to one metre around the base of the trunk. Fertiliser was placed in a shallow band (10 cm deep) made around the tree (0.5 m away from the base of the tree) and then covered with soil. The fertilisers were applied only once in January–February 1992 on both sites. The experiment lasted for one and half years (January 1992–July 1993).

Table 2. Fertiliser treatments

NPK trial	Treatment	Amount of nutrients applied (kg ha^{-1})		
		Urea	P_2O_5	K_2O
	N0P0K0	0	0	0
	N0P1K1	0	500	100
	N0P2K1	0	800	100
	N1P1K1	500	500	100
	N1P2K0	500	800	0
	N1P0K1	500	0	100

Growth measurements and data analysis

Height and DBH measurements on all the trees in the plot were performed every six months for one-and-a-half years. The height and DBH increments were calculated from the initial and one-and-a-half-year data. One-way analysis of variance (ANOVA) was employed to assess the effects of fertilisers on height and diameter (DBH) growth. Duncan's New Multiple Range Test (DMRT) was used to compare mean values of all the treatments.

Results

Height

NPK fertiliser application increased height growth significantly on both sites (Kemasul and Kerling) (Table 3). In Kemasul, maximum height increment of 7.26 m (70.0% increase over the control) was observed with N1P2K0 treatment whereas an increment of 65.8% was obtained with treatment N0P2K1. However, these two treatments were not significantly different ($p< 0.05$) from each other (Table 3). The results indicate the significance of P, K and N, P combined effects on tree growth. In Kerling, the highest height increment (8.68 m) was recorded with treatment N0P2K1 (101.9% increase over the control). An increase of 88.6% was observed with treatment N1P2K0 although there was no significant difference ($p< 0.05$) between these treatments as was observed for Kemasul. Thus, both the treatments N0P2K1 and N1P2K0 were effective in promoting height growth on both sites.

Table 3. Fertiliser treatments and tree growth in the two sites

Treatment	Growth parameters					
	H1(m)	H4 (m)	H4-H1(m)	D1(cm)	D4 (cm)	D4-D1(cm)
Kemasul						
N0P0K0	13.86b	18.13c	4.27d	15.52a	19.44c	3.92d
N1P0K1	14.22a	19.44b	5.22c	14.83ab	19.64c	4.81c
N0P1K1	13.95ab	19.44b	5.49bc	14.58b	19.61c	5.03bc
N1P1K1	14.51a	20.29ab	5.78b	15.18a	20.56b	5.38b
N0P2K1	14.35a	21.43a	7.08a	15.20a	21.36a	6.16a
N1P2K0	13.78b	21.04a	7.26a	14.75b	21.24a	6.49a
Kerling						
N0P0K0	14.49a	18.79c	4.30d	15.73bc	19.57c	3.84d
N1P0K1	14.25a	19.70b	5.45c	17.18a	22.31b	5.13c
N0P1K1	14.07a	19.55b	5.48c	14.86c	20.54c	5.68b
N1P1K1	13.33b	21.05a	7.72b	16.28b	21.42b	5.14c
N0P2K1	12.14c	20.82ab	8.68a	16.66ab	24.00a	7.34a
N1P2K0	13.07b	21.18a	8.11ab	14.94c	21.89b	6.95ab

Note: H1, H4 = heights before and after 1.5 years of fertilisation.
D1, D4 = dbh before and after 1.5 years of fertilisation.
Means with the same letter(s) are significantly not different ($p<0.05$) as determined by Duncan's New Multiple Range Test.

Diameter

Diameter increment (DBH) was enhanced by NPK fertilisation on both sites (Table 3). In Kemasul, maximum DBH increment (65.6% more than the control) was noted with treatment N1P2K0 although this was not significantly different ($p< 0.05$) from treatment N0P2K1 (57.1% more than the control) (Table 3). In Kerling, N0P2K1 produced maximum diameter increment (91.1% more than the control) although this was not significantly different ($p< 0.05$) from treatment N1P2K0 (81.0% more than the control) (Table 3). The results point out the importance of P, K and N, P combined effects on diameter increment as well. As with height increment, both the treatments (N0P2K1) and N1P2K0 were effective in enhancing diameter increment. In percentage terms, Kerling recorded a higher height and diameter increment than Kemasul.

Foliar nutrient concentration and growth parameters

Foliar nitrogen, phosphorus, potassium, calcium and magnesium concentrations were significantly ($p<0.05$) increased as a result of NPK fertilisation on both sites (Table 4). In Kemasul, the increase in foliar N concentration was from 1.74 to 2.08% (treatment N1P1K1) and from 1.84 to 2.10% (treatment N1P2K0) in Kerling due to fertilisation. NPK fertilisation increased foliar P from 0.08 to 0.14% (treatment N1P1K1) in Kemasul and from 0.12 to 0.16% (treatment N0P2K1) in Kerling. Foliar K concentration increased from 0.76 to 0.91% (treatment N1P1K1) in Kemasul and from 0.72 to 0.98% (treatment N0P1K1) in Kerling due to NPK fertilisation. Similarly, foliar Ca concentration was observed to increase from 0.62 to 0.71% (treatment N0P2K1) in Kemasul and from 0.67 to 0.76% (treatment N1P1K1) in Kerling. For foliar Mg, the concentration increased from 0.10 to 0.13 % (treatment N0P2K1) in Kemasul and from 0.13 to 0.15% (treatment N0P1K1) in Kerling. The treatments N0P2K1, N1P1K1 and N1P2K0 produced higher uptake of most of the nutrients in the foliage on both the sites. This suggests the beneficial combined effect of PK, NP and NPK on foliar nutrient concentrations.

Table 4. Foliar nutrient concentrations and growth parameters

Treatment	Nutrient concentrations (%)					Growth parameters	
	N	P	K	Ca	Mg	Ht (m)	Dbh (cm)
Kemasul							
N0P0K0	1.74f	0.08d	0.76cd	0.62bc	0.10bc	2.84d	2.61d
N0P1K1	1.80e	0.10c	0.74d	0.54d	0.12ab	3.67bc	3.36bc
N0P2K1	1.84d	0.13ab	0.87ab	0.71a	0.13a	4.72a	4.10a
N1P1K1	2.08a	0.14a	0.91a	0.64b	0.12ab	3.85b	3.58b
N1P2K0	2.02b	0.11bc	0.80c	0.60bc	0.09c	4.85a	4.32a
N1P0K1	1.92c	0.10c	0.87ab	0.54d	0.10bc	3.48c	3.21c
Kerling							
N0P0K0	1.84d	0.12bc	0.72a	0.67c	0.13b	2.87d	2.55d
N0P1K1	1.92bc	0.15a	0.98a	0.74a	0.15a	3.65c	3.79bc
N0P2K1	1.95b	0.16a	0.86b	0.69bc	0.12bc	5.79a	4.89a
N1P1K1	2.05a	0.14ab	0.82c	0.76a	0.11c	5.15b	3.43b
N1P2K0	2.10a	0.11c	0.88b	0.75a	0.11c	5.41ab	4.64a
N1P0K1	1.98b	0.13b	0.86b	0.72b	0.12bc	3.64c	3.42c

Note: Means with the same letter (s) are not significantly different ($p<0.05$) as determined by Duncan's New Multiple Range Test. Parameters were monitored one year after the fertilisation.

Figures 2 and 3 show the effects of P fertiliser on height and diameter increments respectively, on both the sites. The results depict the importance of P fertiliser in enhancing growth and show that 800 kg P_2O_5 ha^{-1} produced maximum increment for both the growth parameters.

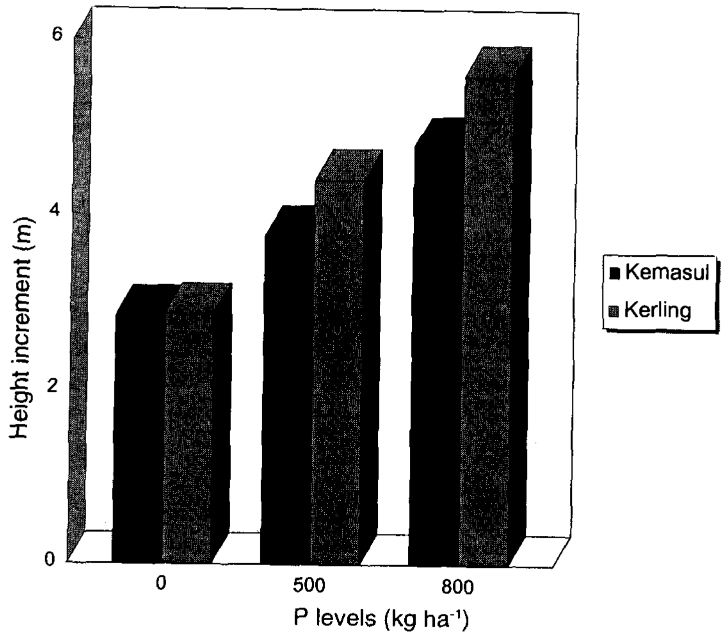

Figure 2. Height increment at the two sites

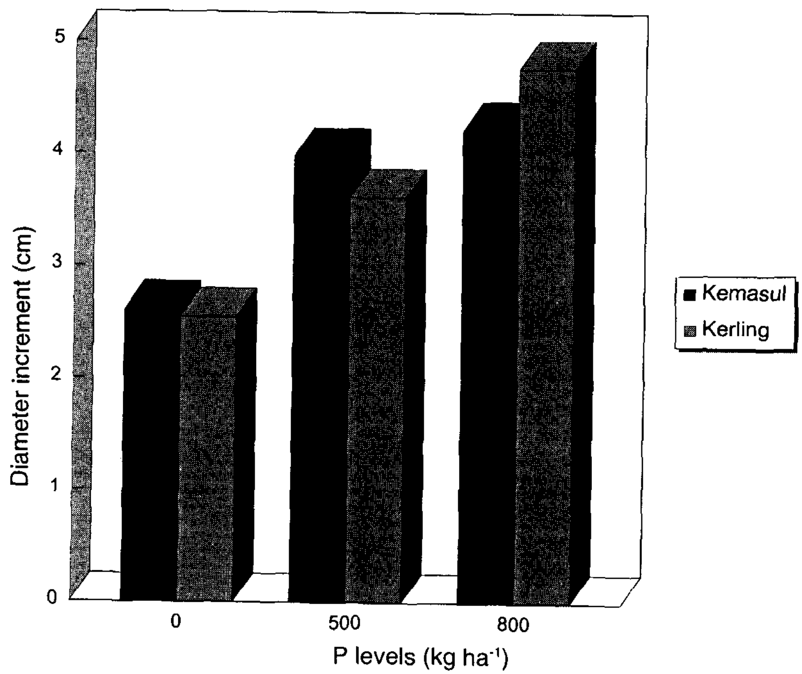

Figure 3. Diameter increment at the two sites

Paudyal and Nik Muhamad (1992), in an earlier study, reported the foliar nutrient concentrations of 5-y-old *A. mangium* plantation in Kemasul as 1.82% for N, 0.12% for P, 0.71% for K, 0.66% for Ca and 0.07% for Mg with ht (MAI) and dbh (MAI) as 3.38 m and 3.43 cm respectively. The present study clearly indicated the effects of fertiliser application in enhancing foliar nutrient levels and growth parameters. In Kemasul, maximum growth parameters were recorded for the following range of foliar nutrient concentrations (%): N—1.84 to 2.02, P—0.11 to 0.13, K—0.80 to 0.87, Ca—0.60 to 0.71 and Mg—0.09 to 0.13. For Kerling, maximum growth parameters were observed for the following range of foliar nutrient concentrations (%): N—1.95 to 2.10, P—0.11 to 0.16, K—0.86 to 0.88, Ca—0.69 to 0.75 and Mg—0.11 to 0.12.

Discussion

The results of the present study are in agreement with the findings by other researchers (Anthony 1971, Lim & Sundralingam 1974, Abang Naruddin 1981) where better growth responses of *Pinus caribaea* seedlings to N and P application on different soil types have been reported. The favourable growth responses from N and P application to *Tectona grandis* (Sundralingam 1982), *Dryobalanops aromatica* and *D. oblongifolia* seedlings (Sundralingam 1983) and *Gmelina arborea* seedlings (Kamis & Ismail 1986) have been well documented. The effect of K and P has also been shown to increase height growth of Caribbean pine seedlings (Manikam & Srivastava 1980).

NPK fertilisation resulted in tremendous height and diameter increments of the test trees on both sites. However, increments in Kerling were comparatively higher than in Kemasul. For example, Kemasul showed a maximum height increment of 70.0% whereas in Kerling it was 101.8%. Similarly, Kemasul recorded a 65.5% increase in diameter compared to 91.1% increment in Kerling. This might have been due to the age factor as trees in Kerling were only 3.5 y old as compared to those in Kemasul, which were 5 y old and needed more space for crown expansion. The other factors that might have caused this difference in growth response are seed source, weed effects and climatic factors. The results also show that NP and PK effects were important for increasing tree height and diameter. However, NP had a more pronounced effect in Kemasul and PK in Kerling. The PK effects in Kerling might be attributed to higher soil K concentration.

Trees suffering from nutrient deficiency generally have lower than normal foliar concentrations of the nutrients. In the case of *A. mangium* the deficiency levels of different nutrients have not been established yet. However, the results from the present study indicated that satisfactory growth of the trees can be maintained by keeping foliar nutrient levels within a certain range. This information might be beneficial from the management point of view in the stands of similar age and site characteristics. Moreover, the results could not provide a clear picture on the optimum level of fertiliser application. It can be safely assumed that higher levels of fertiliser application might result in more increments. However, the results indicate that P is one of the most important nutrients for enhancing tree growth. Thus, phosphorus at the rate of at least 800 kg P_2O_5 ha^{-1} is necessary for enhancing tree growth on both sites. Potassium as K_2O may be applied at 100 kg ha^{-1}. Nitrogen, on the other hand, may be applied in Kemasul at about 500 kg urea ha^{-1} given the higher interaction between N and P. However, as there was no significant difference between NP and PK effects in Kemasul, P and K application should be sufficient.

Conclusion

Both the study sites were deficient in N, P and K and application of NPK fertilisers enhanced tree height and diameter growth significantly. Phosphorus at the rate of at least 800 kg P_2O_5 ha^{-1} is necessary for maximising growth of trees. Potassium as K_2O may be applied as 100 kg ha^{-1}. A satisfactory growth of *A. mangium* trees could be maintained by keeping foliar nutrient concentrations of different elements within a certain range.

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