Pertanika J. Trop. Agric. Sci. 25(2): 107 - 113 (2002)

ISSN: 1511-3701

Growth Response of Teak (*Tectona grandis* L.f.) Seedlings to Nitrogen, Phosphorus and Potassium Fertilizers

SHEIKH ALI ABOD & MUHAMMAD TAHIR SIDDIQUI
Faculty of Forestry, Universiti Putra Malaysia
43400 UPM, Serdang, Selangor, Malaysia

***Keywords:* Fertilizers, growth response, Penambang soil series, Tectona grandis**

ABSTRAK

*Jati (*Tectona grandis *L.f.) adalah salah satu jenis kayu balak yang bermutu tinggi di dunia. Satu kajian di rumah kaca telah dilakukan untuk mengetahui tindak balas tumbesaran anak benih jati kepada baja N, P dan K. Keputusan kajian ini menunjukkan bahawa berat akar, daun dan berat keseluruhan anak benih jati di pengaruhi dengan bererti oleh kesemua fakta utama iaitu N, P dan K. Pertambahan ketinggian, berat daun, berat pucuk dan panjang akar menunjukkan tindak balas statistik yang bererti kepada baja N dan P. Kesan-kesan utama N dan K tetapi bukan P didapati bererti kepada pertambahan perepang. Hanya kesan utama N kepada nisbah akar : pucuk didapati bererti secara statistik. Kajian ini juga menunjukkan bahawa 564 kg/ha ammonium sulfat dan 300 kg/ha P205 dengan 75 kg/ha K2O diperlui untuk menggalakkan tumbesaran ketinggian, perepang dan berat keseluruhan anak benih jati di tapak semaian.*

ABSTRACT

T*eak (*Tectona grandis *L.f.) is one of the high quality timber species in the world. A greenhouse experiment was conducted to determine the growth response of teak seedlings to N, P, K fertilizers. The results of the present study indicated that root weight, leaf area and total plant weight of the teak seedlings were significantly affected by all the three main factors i.e. N, P and K. Height increment, leaf weight, shoot weight and root length showed statistically significant responses to N and P fertilizers. The main effects of N and K but not of P were statistically significant for diameter increment. There was significant main effect of N only for root-shoot ratio. The present study also revealed that the application of 564 kg/ha ammonium sulphate, 300 kg/ha triple superphosphate and 75 kg/ha muriate of potash are required to enhance height and diameter growth and total plant weight of teak seedlings at nursery stage.*

INTRODUCTION

The increasing demand for forest products has steadily depleted the tropics of their natural forest resources. In consequence, afforestation and replanting programmes have gained momentum. Malaysia's natural forest resources currently estimated at less than 60% of the total land area are being depleted drastically because of the rapid industrial development, particularly in the Peninsular. According to Zainal (1992), deforestation in Peninsular Malaysia increased from about 0.25 million ha annually between 1981 – 1985 to 0.48 million ha in 1989. In view of the indiscriminate logging activities, it is envisaged that Malaysia would soon find it difficult to meet the growing demand for hardwood by the timber industry. Malaysia embarked on a Compensatory Forest Plantation Programme in the early eighties(CFPP) as a move to bridge the gulf between supply and demand for timber. The project involves the planting of fast-growing hardwood species,namely *Acacia mangium*, *Gmelina arborea* and *Paraserianthes falcataria* as general utility timber at a rotation of 15 years (Yong 1984). More than 171,000 hectare of forest plantations were established as at October 1996 (Abod 1998). However, about 80% of the species planted was *A. mangium*. The current policy has shifted its emphasis for sawlog production to sentang (*Azadirachta excelsa*), rubber (*Hevea* spp.), teak and fast growing indigenous species.

Commercial planting of teak was initiated in the 1950s in the Northern States of Perlis and Kedah with the aim of producing high quality timber. It is now common to see the species being planted on the road shoulders and vacant lands on both sides of the North – South highway of P. Malaysia by the North-South Highway Corporation (PLUS).

Teak (*Tectona grandis* L.f) is one of the most sought-after timbers of the world. It has worldwide reputation because of its sterling qualities. Not only is it aesthetically appreciated, its superior properties have also made it the prime timber for furniture, carvings and excellent building material. Teak possesses a blend of beauty, strengh and durability, which is far superior to any other timbers of the world. In addition, teakwood is also resistant to attack by termites and fungi.

Unfertilized teak stands show a slow growth rate which can discourage the private sector from investing in commercial teak plantations. Proper fertilization offers potential for increasing the growth rate of teak with a possibility of shortening its rotation period. Fertilizer use is of paramount importance in the tropics where the soils loose their fertility at a very rapid rate especially after the removal of natural vegetation for plantation establishment. Relatively few studies have been carried out to determine the fertilizer needs of teak. A recent trial conducted at Universiti Putra Malaysia showed that teak seedlings responded well to high fertilization and the presence of the endomycorrhizae fungsi (Junaini 1995). In Malaysia, the positive effect of phosphorus fertilizer on teak was reported by Sundralingam (1983). Other fertilizer trials conducted on commercial forest species mainly focused on pine plantations in Malaysia (Abod 1982). In view of this, a fertilizer trial was conducted in the greenhouse of Forest Research Institute Malaysia (FRIM) sub-station Mata Ayer, Perlis. The trial aimed to identify the most suitable levels on N, P and K for optimum growth of teak seedlings.

MATERIAL AND METHODS

The study site (FRIM sub-station) is situated at an elevation of 33 m above sea level at Mata Ayer, Perlis. It falls within latitude 6° 40' North and longitude 100° 15' East. This site was selected because of its favourable climate for the growth of teak. Teak generally favours a climate with a distinct dry season (monsoonal climate) in a year. Top soil was collected from the 0-30 cm depth from Compartment 17 of the abovementioned site. The soil belongs to Penambang Series, which is a recent alluvial deposit, mostly confined to the river banks of Sungai Chuchoh. The soil is a strong micaceous fine sandy clay loam with a friable and weak structure (Amir 1983).

The soil was air dried and passed through a 2 mm mesh sieve before being filled into 4 kg polybags. It was then thoroughly mixed with fine river sand in the proportion of 3:1 in order to ascertain better aeration and drainage. Chemical analysis of the potting material showed that it contained 1.21% organic carbon, 0.12% nitrogen, 5.10 ppm available phosphorus, 0.24% exchangeable potassium. The pH was 4.35.

Two-week-old *Tectona grandis* seedlings of uniform height and vigour were obtained from the nursery of Mata Ayer F.R. Perlis. The seedlings were transplanted from the nursery bed to polybags of 13 cm in diameter x 10 cm in height in December 1994. Polybags were used to avoid diffusion of fertilizers through the walls (which is a phenomenon common in clay pots). Nitrogen (N) and phosphorus (P) were applied at three levels and potassium (K) at two levels. The dosages used are as given in Table 1. Fertilizers were applied one month after transferring the seedlings into polybags. The seedlings were watered twice daily. Regular weeding and loosening of top soil were carried out to ensure maximum dispersal and mobilization of nutrients into the substratum. The treatments in all possible combinations were assigned at random, giving a total of 114 polybags including 6 control plants. Each treatment was replicated six times.

Height and diameter increments of seedlings were measured regularly every four weeks for 12 months. Total height was measured with the aid of a meter ruler from the base of the stem at the soil level to the terminal bud of the main stem. Collar diameter was measured at the root collar with the help of a vernier caliper to the nearest 0.01mm. Dry matter production was obtained by carefully uprooting the seedlings from the pot. The roots were thoroughly washed and each plant separated into leaves, shoot and roots. All plant parts were put in the oven at 70 - 85° C for 36-48 hours to dry to a constant weight. The dry weight of each component was

TABLE 1
Levels of nutrients applied

Commercial fertilizers	Element	Nutrients (g) added per pot		
		Level 1	Level 2	Level 3
Ammonium sulphate (21% N)	N	0.20 (150 kg/ha)	0.75 (564 kg/ha)	0.90 (677 kg/ha)
Triple superphosphate (48% P_2O_5)	(P_2O_5)	0.20 (150 kg/ha)	0.40g (300 kg/ha)	0.60 (451 kg/ha)
Muriate of Potash (60% K_2O)	(K_2O)	0.10 (75 kg/ha)	0.20 (150 kg/ha)	

determined to the nearest 0.01 g with a top-loading metre balance. Root-shoot ratio was calculated as the ratio of the dry weight of root to the dry weight of the shoot. Height increment was obtained by subtracting the initial height which was taken before the application of nutrients from the final readings taken at the end of the experiment. Leaf area was measured by the leaf area meter, and diameter by vernier calipers. Root length was measured from collar to the tip with a meter ruler. The results obtained were subjected to 3 way ANOVA, analyzing the main effects of nitrogen (N), phosphorus (P) and potassium (K) and their interactions on growth. Duncan' New Multiple Range test was used to compare the significance for differences between treatments (Gomez & Gomez 1976).

RESULTS AND DISCUSSION

Analysis of variance (Table 2) showed that root weight, leaf area and total plant weight of the seedlings were significantly ($p<0.01$) affected by all the three main factors i.e. N,P and K. Height increment, leaf weight, shoot weight and root length showed statistically significant responses to N and P fertilizers. The main effects of N and K but not of P were statistically significant ($p<0.01$) for diameter increment. There was significant ($p<0.05$) main effect of N only for root-shoot ratio.

Height Increment

Application of either N or P fertilizers significantly increased the height increment of teak seedlings (Table 2). The increment was most significant at level 1 where the difference between fertilized and unfertilized plants was about 200 per cent (Table 3). Increasing the quantity of any of the elements from level 1 to 2 resulted in only small increases (Table 3). There were significant interactions between NxK and PxK but not between NxPxK for height increment (Table 2).

Diameter Increment

The main effects of N and K but not of P fertilizers were significant ($p<0.01$) on diameter increment (Table 2). The most significant increment was observed at level 1 where the difference between fertilized and unfertilized plants was about 150% (Table 3). Subsequent increases in the levels of nutrients did not increase diameter growth. There were significant interactions between NxK and NxPxK but not for other combinations (Table 2).

The improved growth in response to N and P application is not unusual. As N promotes vegetative growth, consisting of stems and leaves, plants receiving adequate N show vigorous growth, large leaves, and long stems (Plaster 1985). Phosphorus is intimately associated with all life processes and is a vital constituent of every living cell. It is also important because a high concentration of P is found in plant parts that are growing rapidly. Diameter increment was significantly ($p<0.01$) enhanced by N and K but not by P fertilizer. Basically, N has been called the growth element because it is a vital part of plant protoplasm. Protoplasm is the seat of cell division and, therefore, plant growth (Sopher and Baird 1982). It is also one of the fundamental units in proteins, nucleic acid and chlorophyll; it controls the formation of foliage, determines the amount of plant production, and consequently that of diameter increment (Novoa and Loomis 1978). K, on the other hand, is involved in enzyme activity, and a deficiency is said to hinder the translocation of carbohydrates and nitrogen metabolism (Kramer and Kozlowski 1979).

TABLE 2
Results of analyses of variance on teak growth parameters

Growth Parameters	Sources of Variation						
	Main factors			2-way interaction			3-way interaction
	N	P	K	NP	NK	PK	NPK
Height increment	*	**	ns	ns	**	**	ns
Collar diameter	**	ns	**	ns	**	ns	**
Leaf weight	**	**	ns	ns	ns	**	**
Shoot weight	**	**	ns	**	ns	**	ns
Root weight	**	**	**	ns	ns	ns	ns
Root/shoot ratio	**	ns	ns	ns	*	*	ns
Leaf area	**	**	**	**	ns	ns	ns
Root length	**	**	**	**	ns	**	**
Total plant weight	**	**	**	**	ns	ns	ns

** Significant at 1% level
* Significant at 5% level
ns Non-significant

Root Length

The main effects of N and P were significant ($p<0.01$) on root length (Table 2). Root length was increased by nearly 300 per cent when fertilized using N or P or K. Difference between levels 1, 2 and 3 are not statistically significant for each of the elements, although level 2 recorded maximum length (Table 3). There was significant interaction between NxP and PxK but not for other combinations (Table 2).

Total Leaf Area

Total leaf area was significantly affected by the main effects of N, P and K respectively (Table 2). Plants fertilized with N, P or K had a significantly larger leaf area than the control. Total leaf area was most significant at level 2 of N where the difference between fertilized and unfertilized plants was about 400 per cent (Table 3). Subsequent increase in the quantity of nutrients resulted in marked increases of the leaf area. There was significant interaction between NxP only (Table 2). In general, the main effects of N, P and K on the leaf area were more pronounced than that of the combined effect (Table 2).

Dry Matter Production

Total Plant Weight

Total plant weight showed significant differences with the main effects of N, P and K similar to that of the leaf area (Table 2). The most significant difference was observed at level 3 or P where the difference between fertilized and unfertilized plants was more than 200 per cent. The only significant interaction was between NxP (Table 2).

Leaf Weight

Leaf weight was significantly affected by the main effect to N and P. The only significant interaction was for PxK as evident from Table 2. Leaf weight was most significant at level 3 of P where the difference between fertilized and unfertilized plants was 200 per cent (Table 3).

Shoot Weight

The main effects of N and P on shoot weight were significant ($p<0.01$) and similar for leaf weight (Table 2). Shoot weight showed the highest difference at level 3 of P where the difference between treated and untreated seedlings was about 200 per cent. Increases in P and K levels increased shoot weight significantly (Table 3). There were statistically significant ($p<0.01$) interactions between NxP and PxK. Table 3 also reveals that shoot weight increased significantly with increase in nutrient levels especially for N and P but not for K.

Root Weight

The main effects of N, P, K fertilizers were significant ($p<0.01$) on root weight as evident from Table 2. All interactions between the elements were non-significant ($P<0.05$). Root weight was significant at level 2 of N where the differ-

TABLE 3
Comparison between treatments for different growth parameters of *T. grandis* seedlings after 12 months of fertilizer application

		Lfwt (g)	Shwt (g)	Rtwt (g)	Tpwt (g)	Ht (cm)	R/S ratio*	Dia (mm)	Lfarea (cm2)	Rtlen (cm)
N	0	4.9d	9.5b	4.2c	18.6	10.3b	(0.4a)-0.91	8.0c	356.5	9.0b
	1	8.2c	16.0a	6.1b	13.3b	27.8a	(0.2)-1.60	11.3a	588b	25.1a
	2	10.8a	18.3a	9.4a	38.5a	30a	(0.1a)-2.30	9.2b	1002.2a	28.3a
	3	9.9b	18.5a	8.8a	37.2a	29.3a	(0.2)-1.60	9.7b	674.5b	25.2a
	LSD	1.34	2.5	0.89	3.48	2.6	-0.9	0.10	118.8	3.87
P	0	4.9c	9.5c	4.2b	18.6c	10.3b	(0.4a)-0.91	8.0b	356.5c	9.0b
	1	9.5b	16.7b	7.8a	24b	27a	(0.2a)-1.60	9.6a	703.7b	23.9a
	2	9.7b	16.8b	8.4a	34.9b	29.8a	(0.1a)-2.30	10.4a	844.3a	27.2a
	3.	11.4a	19.3a	8.7a	39.4a	30.4a	(0.2a)-1.60	10.2a	788.3ab	27.5a
	LSD	1.34	2.5	0.89	3.48	2.6	-0.9	0.10	118.8	3.87
K	0	4.9b	9.5c	4.2c	18.6c	10.3b	(0.4a)-0.91	8.0b	356.5b	9.0c
	1	9.7a	18.5b	7.8b	36b	28.6a	(0.2a)-1.60	10.5a	740.1a	25.5b
	2	10.7a	19a	8.8a	38.5a	129.5a	(0.2a)-1.60	9.6a	847.4a	27.1a
	LSD	1.40	2.60	0.96	3.60	2.71	-0.3	0.11	123.8	4.0

Note:
Lfwt=Leaf weight
Shwt=Shoot weight
Rtwt=Root weight
Tpwt=Total plant weight
Ht=Height increment
Similar letters indicate not significant
R/S ratio=Root-shoot ratio
Dia=Diameter
Lfarea=leaf area
Rtlen=Root length
LSD=Least Significant Difference
* Values in the parentheses are actual values

ence between fertilized and unfertilized plants was about 300 per cent (Table 3). Increasing the quantity of any of the elements from levels 1 to 2 and 3 resulted in only small increases.

It is evident from the results that total leaf area, total plant weight and root weight were significantly ($p<0.01$) increased by the main effects of N, P and K fertilizers (Table 2). These parameters are interlinked and dependent on each other. For example, in general, a greater leaf area will increase the rate of photosynthesis and ultimately increase the total weight i.e. leaf, shoot and root weights.

Root-Shoot Ratio

The root-shoot ratio was significantly affected only by the main effect of N (Table 2). There was significant interaction ($p<0.05$) between NxK and NxP treatments (Table 2). There was a significant increase at level 2 of N but it decreased abruptly at level 3. In general, there was no significant effect of fertilizers except of N($p<0.05$) on the root-shoot ratio (Table 3).

The low root-shoot ratio recorded in this experiment showed that seedlings gave more shoot growth than root growth. This is interesting since shoot is the harvest index in forest trees. Kamis and Ismail (1986) and Ogbonnaya (1994) had also reported low root-shoot ratio in their studies. Previous studies of nutrient requirements of teak in Malaysia (Sundralingam 1983) and in India (Bhatnagar *et al.* 1969; Kishore 1987) showed significant increases in height and diameter of seedlings as a result of N and P fertilizer applications.

The application of fertilizers to promote early growth of trees in plantations is now an established practice. For the compensatory plantations in Peninsular Malaysia, Johari and Chin (1986) recommended application of 120 g rock phosphate into each planting hole at the time of planting, followed by another 120 g of rock phosphate and 60 g of triple superphosphate one year after planting (an equivalent at 300 kg/ha). Based on the present study, these dosages are not sufficient for teak, as it requires high nutrients for its growth.

In the tropics, appreciable growth responses especially to P have been documented for *Pinus caribaea* var. *hondurensis* by Lim and Sundralingam (1974), Sundralingam and Ang (1975) and Cameron *et al.* (1981) because tropical soils are deficient in P. But this does not hold true in all cases. For instance, Srivastava and Naruddin (1979) reported that N and P were important for height increment of *P. caribaea* seedlings on Durian soil. Paudyal and Majid (1997) observed good response only to N fertilizer on height and diameter of Acacia mangium on Serdang soils. Kamis and Ismail (1986) reported that on Bungor soil, P, N and their interactions were important for maximum height increment of *Gmelina arborea.* Ogbonnaya (1994) also reported that NK combination contributed significantly to the height increment of *G. arborea* in Nigeria. The present study also indicated a similar pattern of response to NK interaction for height and diameter of teak seedlings.

CONCLUSION

The results of the present study indicate that an application of 464 kg/ha ammonium sulphate, 300 kg/ha triple superphosphate and 75 kg/ha muriate of potash can enhance initial height, diameter growth and total plant weight of teak seedlings. It is suggested that level 1 of N, P and K is sufficient to increase the growth of teak seedlings. It would not be economical to use high dosages of fertilizers as the subsequent increase in growth due to high levels of fertilizers gives diminishing results. However, these fertilizer levels may vary depending on different soil types and plant species. This pot experiment provides a basis for fertilizer trials in the field.

ACKNOWLEDGEMENT

We sincerely thank the Director General of the Forest Research Institute Malaysia for allowing us to use the facilities at the Insitutes' Research sub-station in Mata Air, Perlis.

REFERENCES

ABOD, S.A. 1982. Plantation forestry practices in Peninsular Malaysia. In *Proceedings on Tropical Forests: Source of Energy Through Optimization and Diversification* ed. P.B.L. Srivastava, Abdul Manap Ahmed, Kamis Awang, Ashari Mukhtar, Rozali Abdul Kadar, Freezaillah Che Yom and Lee Su See. 349-360p. 11-15 Nov. 1980. Universiti Pertanian Malaysia.

ABOD, S.A. 1998. Development of forest plantations in Malaysia. A country report presented to *Asian Productivity Organization Multi-Country Study Mission on Afforestation and Tree Breeding,* 20p. 4 – 13 March, Tokyo, Japan.

AMIR, H.M.S. 1983. Teak plantation establishment in Mata Ayer Forest Reserve, Perlis in relation to soil type. F.R.I. Reports. *Forest Research Institute Malaysia* **33**:19-18.

BHATNAGAR, H.P., B.B. GUPLA, RAULHAN and D.N. JOSHI. 1969. Preliminary studies on the nutritional requirements of teak (Tectona grandis). *Indian Forester* **95**: 488-495.

BLACK, C.A. 1968. *Soil Plant Relationship.* 451p. New York: John Wiley and Sons Inc.

CAMERON, D.M., S.J. RANCE and E.R. WILLIAM. 1981. Fertilizer responses of *Pinus caribaea* var. *hondurensis* on a tropical red earth. *Australian Forestry Research* **11**: 35-45.

GOMEZ, K.A and A.A. GOMEZ. 1976. Statistical procedures for agricultural research with emphasis on rice. p. 98-103. Philippines: The International Rice Research Institute.

JOHARI, B. and T.Y. CHIN. 1986. Review of plantation experiences in Peninsular Malaysia. In the *Ninth Malaysian Forestry Conference,* 21p. 13-20 October, Forestry Department, Kuching, Sarawak, Malaysia.

JUNAINI, A. 1995. Response of forest (*Tectona grandis* and *Kayea grandis*) to basicular – arbuscular mycorrhizea inoculation. B. Sc (Agri) Thesis. p. 1-50 (unpublished).

KAMIS, A. and K. ISMAIL. 1986. Growth response of *Gmelina arborea* Roxb. Seedlings to N, P, and K fertilizers on Bungor soil. *Malaysian Forester* **9 (4)**: 357-370.

KISHORE, N. 1987. Preliminary studies on the effect of phosphatic fertilizers on teak plantation. *Indian For.* **9(4)**: 35-37.

KRAMER, P.J. and T.T. KOZLOWSKI. 1979. *Physiology of Woody Plants.* 811p. New York, San Francisco, London: Academic Press.

LIM. F.Y. and P. SUNDRALINGAM. 1974. Some preliminary results of fertilizer applications on the growth of a 6 year old *Pinus caribaea* Mor. var *hondurensis* stand. *Malaysian Forester* **37**: 120-126.

NOVOA, R and R.S. LOOMIS. 1978. Nitrogen and plant production. *Plant Soil* **58**:177-204 .

OGBONNAYA, C.I. 1994. Growth and histo-chemical response of Gmelina arborea seedlings to application of N and K fertilizers and their combinations on oxisolic soil. *Journal of Tropical Forest Science* **6(4)**: 363-378.

PAUDYAL, B.K. and N.K. MAJID. 1997. N, P, K fertilizer pot trials of *Acacia mangium* Willd. seedlings. *Malays. Appl. Biol.* **26(2)**: 21-27.

PLASTER, E.J. 1985. *Soil Science and Management.* 551 p. New York: Delmer Publishers.

SOPHER, C.D. and J.V. BAIRD. 1982. *Soils and Soil Management.* 750 p. Virginia: Reston Publishing Company, Inc.

SRIVASTAVA, P.B.L and A.Z. NARUDDIN. 1979. The response of *Pinus caribaea* Mor. var hondurensis seedlings to nitrogen, phosphorus and potassium fertilizers. *Plant Soil* **51**: 215-232.

SUNDRALINGAM, P. and T.B. ANG. 1975. Response of *Pinus caribaea* var. *hondurensis* to fertilization on Bungor soil of Rantau-Panjang Forest Reserve. *Malaysian Forester* **38**: 135-139.

SUNDRALINGAM, P. 1983. Some preliminary studies on the fertilizer requirements of teak. *Malaysian Forester* **45**: 361-366.

YONG, C.T. 1984. Compensatory plantations in Peninsular Malaysia. Paper presented at a *Seminar on Forest Plantations Development in Malaysia.* 32 p. 9-14 July. Kota Kinabalu, Sabah.

ZAINAL, A. 1992. Rehabilitation of degraded secondary forests: A country report Malaysia. *MAB Regional Workshop on Rehabilitation of Degraded Secondary Forests.* 10 p. 17-18 February. Kuala Lumpur.

(Received: 3 July 2001)
(Accepted: 14 May 2002)