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TEAK (*Tectona grandis* Linn. f) ITS NATURAL DISTRIBUTION AND RELATED FACTORS

*Apichart Kaosa-ard**

ABSTRACT

Teak (*Tectona grandis* Linn. f.) occurs naturally only in India Burma, Thailand and Laos. The distribution of this species is discontinuous. Teak in Indonesia was introduced about 400-600 years ago. There are a number of factors controlling the distribution and growth of teak. The important factors are rainfall/soil moisture, temperature, light, geological formation and soil conditions. The responses of teak to these individual factors are revealed in this paper.

INTRODUCTION

Teak is one of the most valuable timber of the tropics. It is extensively used for ship building, furnitures, carving and numerous other purposes. The properties of teak which make it so valuable are lightness with strenght, stability, durability, ease of working without cracking and splitting, resistance to termites, resistance to fungi, resistance to weather and non-corrosive properties. The physical and mechanical properties of the teak timber are also similar to or even superior to other well-known timbers of the temperate region. The comparisons of physical and mechanical properties of the teak timber and some timbers from America and European countries are shown in Table 1.

Owing to its timber qualities, teak has been planted outside its natural range since the 14th–16th century (ALTONA, 1922a). Large scale planting programmes of this species have also been set up in several countries both within and outside teak natural range. Such programmes, however, require a great deal of informations dealing with natural distribution and factors controlling the distribution and growth of the species. In this paper, attempt is made to clarify factors involving natural distribution and growth of teak.

* Teak Seed Centre (Ngao, Lampang,), Division of Silviculture, Royal Forest Department, Bangkok, Thailand.

Table 1. Comparative strength of teak and some European and American species.

English Name	Botanical Name	Weight	Strength as a beam	Stiffness as a beam	Suitability as a post	Shock Resisting ability	Shear	Hardness	Shrinkage
Teak	*Tectona grandis*	100	100	100	100	100	100	100	100
Ash	*Fraxinus excelsior*	90	70	85	70	175	120	85	245
Beech	*Fagus sylvatica*	95	65	85	65	110	130	90	–
Douglas Fir	*Pseudotsuga taxifolia*	80	70	100	80	75	85	55	190
Elm	*Ulmus campestris*	75	45	45	40	65	115	70	–
Hickory	*Careya ovata*	105	90	–	85	–	120	–	225
Larch, European	*Larix europea*	80	55	70	65	125	85	50	175
Oak	*Quercus pedunculata*	95	65	80	75	95	110	95	–
Pine, Scots	*Pinus sylvestris*	50	55	80	60	80	70	40	170
Spruce, Sitka	*Picea rubra*	65	50	80	60	75	70	35	180
Walnut	*Juglans nigra*	85	80	–	80	–	110	75	175

Source : *Anon.* 1956a. *Country Report on Teak*, p. 11.

NATURAL DISTRIBUTION

Teak is a tropical deciduous forest tree species. The species is a member of the family "Verbenaceae" order "Laminales" (TROUP, 1921) and has a set of chromosome number of 2n=36 (HEDEGART & EIGAARD, 1965).

The natural distribution of teak is limited to the Southeast Asian region. The species occurs naturally only in the Indian Peninsular, Burma, Northern Thailand and Northwestern Laos along the northern Thai border (TROUP, 1921; MAHAPHOL, 1954; ANON., 1956; KERMODE, 1957; Ko Ko Gyi, 1972; KAOSA-ARD, 1977). It has a distribution range from the longitude of 73°E in India (TROUP, 1921) to 104° 30 in Thailand (MAHAPHOL, 1954). The northern boundary limit of teak is about 25° 30' N lat. in the Kachin State of Burma (KERMODE, 1957); and its southern boundary limit lies from 9°N lat. in India (TROUP, 1921) through 15°–16°N lat. in Burma (KERMODE, 1957) to 16°30' lat. in Thailand (MAHAPHOL, 1954). Cambodia

and the greater part of Laos were formally believed to be another natural sources of teak (BANIJBHATANA, 1957; HAIG, HUBERMANN & AUNG DIN, 1958). According to KO KO GYI (1972), this part of the Southeast Asian region appears to be outside of the teak range. There is some doubt whether teak in Java and in the small islands of the Indonesian Archipelago, such as Moena and Boetueng, is an indigenous or introduced species. According to ALTONA (1922a, 1922b), the species in these areas was said to be introduced from India by the Hindus sometime between the 14th and 16th century. The natural distribution of teak is illustrated in Figure 1.

FACTORS CONTROLLING DISTRIBUTION AND GROWTH

As mentioned earlier, teak is native to the Southeast Asian region and it occurs naturally only in India, Burma, Thailand and Laos. The distribution pattern of this species within these countries is also discontinuous. Since TROUP(1921) published his famous text entitled, *Silviculture of Indian Trees*, there have been a number of studies on ecology and silviculture of teak attempting to explain the distribution phenomenon of this species. These studies showed that there were many factors controlling the distribution and growth of teak viz. rainfall/soil moisture, temperature, light, geological formation and soil conditions. The responses of teak to these individual factors are the subject of this section.

Rainfall/Soil Moisture

Teak occurs naturally over a wide range of climatic conditions, from very dry localities with annual rainfall as low as 500 mm (e.g. in Khandesh, Nimar and West Kurnool in India) to very moist localities with annual rainfall as high as 5,000 mm, e.g. on the west coast of India SETH & KHAN, 1958). Actually, it grows best and reaches large dimensions in a warm-moist tropical climate with rainfall ranging from 1,270–3,800 mm per annum (KAOSA-ARD, 1977). However, for the production of good timber qualities the species requires a periodic marked dry period of 3–5 months.

Teak appears to avoid both very dry and very moist sites. On dry sites where severe drought stress occurs in the hot-dry season, teak is found

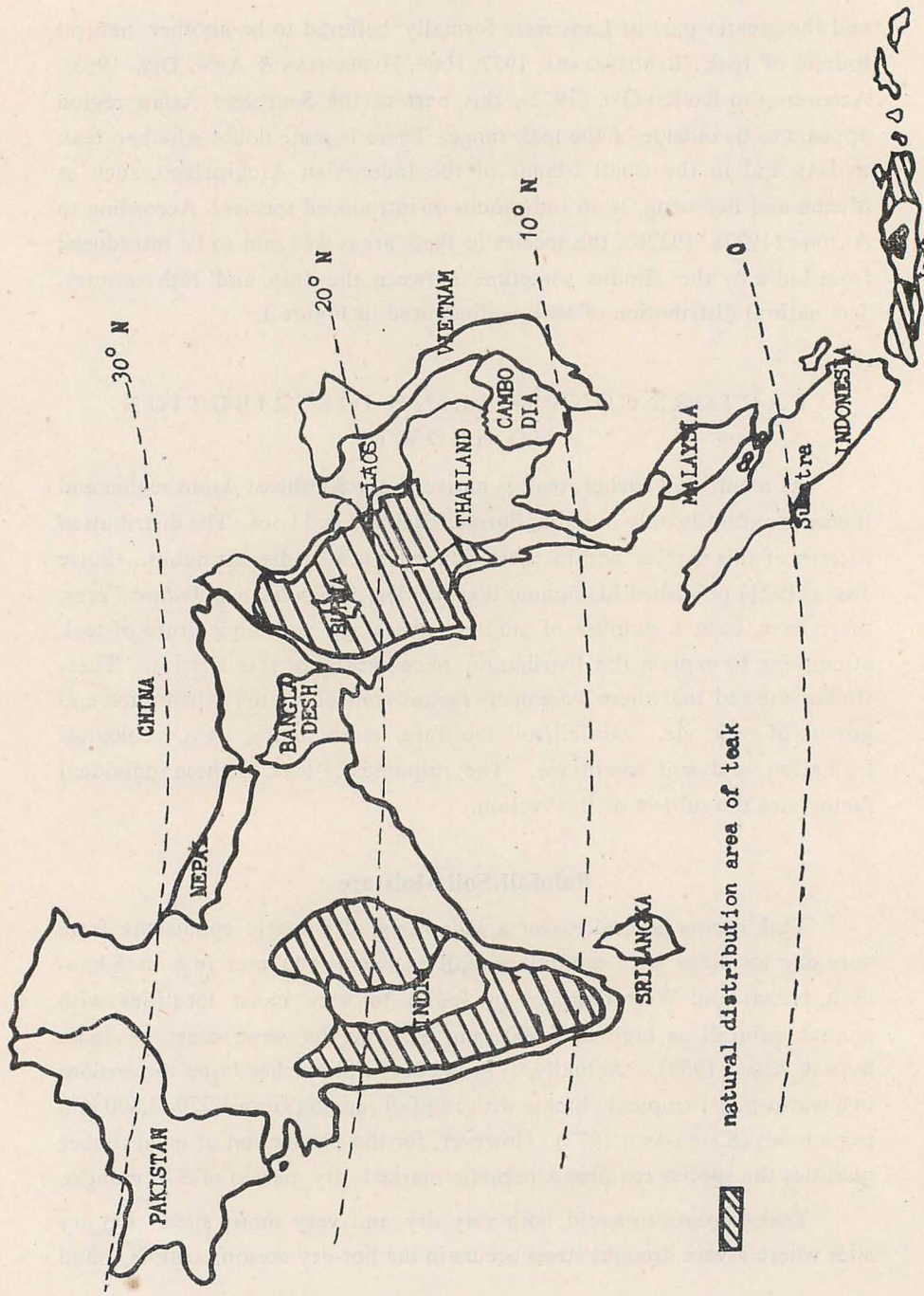

Figure 1. Natural Distribution of Teak (*Tectona grandis*)

to be stunted and shrubby probably due to reduced growth and early loss of apical control. On very moist sites, on the other hand, the tree is usually large and fluted and tends to be replaced by a variety of evergreen forest species. A study under controlled environmental conditions, KAOSA-ARD (1977) reported that teak required a relatively high soil moisture conditions for its growth and development. The seedlings of this species when grown under the high constant soil moisture (near the saturating point) for eight weeks were about five times greater, in term of dry matter production, than those grown under the severe soil moisture stress (near the wilting point). Studies on ecology of the teak forests in India, SETH & KHAN (1958), and CHAMPION & SETH (1968) classified the teak forests in India by correlating the amount of annual rainfall, stand composition and the qualities of teak into five types.

The characteristics of these five forest types are as follows:

1. Very moist teak forest: rainfall over 2,500 mm/annum; deep alluvial or sedimentary loams often clay soils; low (<10) percentage of teak; very dense evergreen undergrowth; little natural regeneration; no fires.
2. Moist teak forest: rainfall 1,600–2,500 mm/annum; deep loamy soils; fair to medium (10–25) percentage of teak; dense undergrowth; fair but patchy natural regeneration; no fires.
3. Semi-moist teak forest: rainfall 1,300-1,600 mm/ annum; moderately deep and loamy soils; medium to high (20-60) percentage of teak; moderate undergrowth; fairly adequate natural regeneration; occasional fires.
4. Dry teak forest: rainfall 900-1,300 mm/ annum; shallow or sandy or stiff clayey top-soil soils; high (50) percentage to almost pure stand of teak; light and patchy undergrowth; group or patchy natural regeneration; frequent fires.

5. Very dry teak forest: rainfall less than 900 mm/annum; poor shallow and rapid run-off or drainage soils; medium percentage of teak; scanty ground cover; practically absent natural regeneration; annual fires.

Similarly, KAOSA-ARD (1979) delineated the teak zones in Thailand for the purpose of seed collection and seed utilization by using the P: T ratio moisture index method (P = annual rainfall in mm, T = annual mean temperature in °C). KAOSA-ARD (1979) divided the teak area in Thailand into four different zones as follows:

Zone 1 : dry-humid zone with the P/T ratio smaller than 40
Zone 2 : medium-humid zone with the P/T ratio of 40-50
Zone 3 : moist-humid zone with the P/T ratio of 50-60
Zone 4 : wet zone with the P/T ratio of greater than 60

The teak seed zones of Thailand as delineated by KAOSA-ARD (1979) are illustrated in Figure 2.

Temperature

Temperature is one of the most important factors controlling distribution, growth and development of teak. Naturally, teak occurs over a wide range of climatic conditions, varying from one locality where the maximum temperature may be as high as 48°C for the hottest month to a locality where the minimum temperature may be as low as 2°C for the coldest month (SETH & KHAN, 1958; HAIG *et al*, 1958; CHAMPION & SETH, 1968). It appears that teak grows best in the localities with the mean monthly maximum temperature of about 40°C and mean monthly minimum temperature of about 13°C (HAIG *et al.*, 1958). Studies on growth and development of teak seedlings under controlled temperatures made by KO KO GYI (1972), KANCHANABURANGURA (1976) and KAOSA-ARD (1977) showed that teak seedlings grew best under day/night temperature ranging from 27°/22° to 36/31°C with the most suitable temperature of 30°/25°C. The critical maximum and minimum day/night temperature for growth and development of teak seedlings were about 36°/31° and 21°/16°C, respectively (KO KO GYI, 1972; KANCHANABURANGURA 1976; KAOSA-ARD 1977). KO KO GYI (1972) and

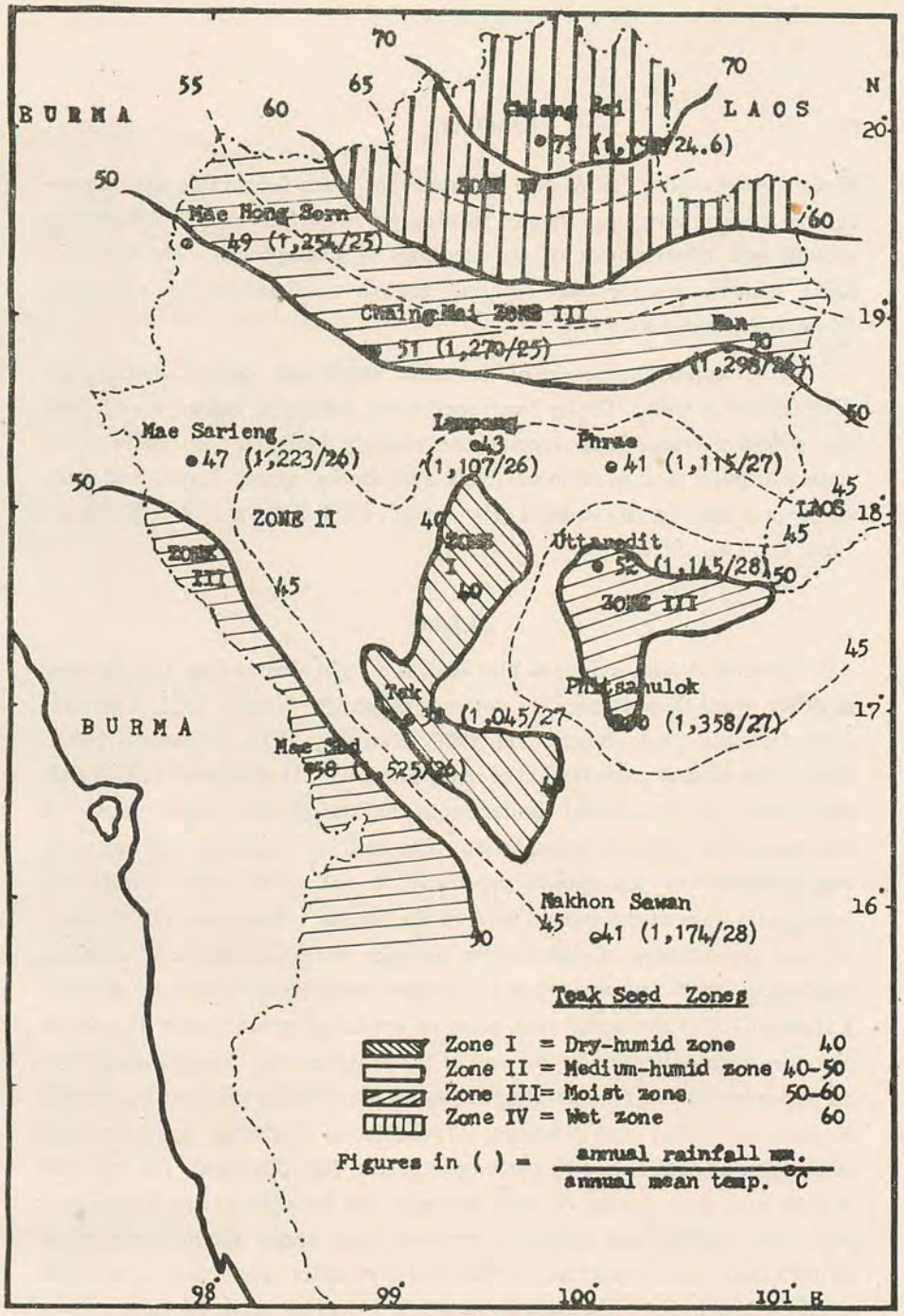

Figure 2. Thailand teak seed zones. Climatic data recorded for 25 years. From Kaosa-ard (1979).

Sources : India – PURI (1960), KO KO GYI (1972)
Burma – KERMODE (1957), KO KO GYI (1972)
Thailand – MAHAPHOL (1954)
Laos – MAHAPHOL (1954)
Indonesia – GARTNER (1956), KO KO GYI (1972)

KANCHANABURANGURA (1976) also reported that given favourable day temperature, night temperature seemed to play an important role in influencing growth and development of the seedlings of this species. The optimum night temperature for teak seedling growth was between 25° and 28°C (KANCHANABURANGURA, 1976).

Frost appears to be one of the most important factors limiting the distribution of teak. Under frost conditions, seedlings, saplings and even the pole-size trees of this species are severely damaged, especially at the succulent parts such as terminal buds and shoots, young leaves and bark cambium, leading to die-back (HAIG *et al.*, 1958; KOTWAL, 1958; KERMODE, 1964; KADAMBI, 1972.

Light

Several studies indicated that teak is a light demanding tree species; in other word this species is intolerant of shade (TROUP, 1921; KERMODE, 1957; QURESHI, 1964; BHATNAGAR, 1966; KADAMBI, 1972; NWOBOSHI, 1972). Studies on natural regeneration of teak, TROUP (1921), KERMODE (1957) and, KITTINANDA (1969) reported similar result that one of the major causes of the failure in natural regeneration (i.e. seed germination and seedling establishment) of this species especially in the moist teak forests was inadequate light at the ground level of the forests. KERMODE (1957) observed that germination of teak seed in nurseries under natural forest canopies was less than 10%, whereas that in the open nurseries was between 40-50%. KERMODE (1957) also noted that most of seedlings grown under the forest canopies eventually died by the end of the rainy season. Studies on growth and development of teak seedlings under shade of different light intensities, BHATNAGAR (1966) and NWOBOSHI (1972) found that the optimum light intensities, as determined by percentage of the full day-light, for the best growth and development of teak seedings was between 75 and 94 percent. NWOBOSHI (1972), for example, reported that under the light intensities of 100, 75, 53 and 25 percent, (a) the total dry matter production of the teak seedlings grown for eight months were 5.2, 14.6, 11.0, and 0.6 gm, respectively and, (b) the total dry matter production of plants grown by planting of seedling-stumps for eight months were 47.7, 78.2, 64.5 and 21.5 gm, respectively.

Daylenght or photoperiod seems to have minor effects on growth and development of teak at least at the seedling stage (KO KO GYI, 1972; KANCHANABURANGURA, 1976). KO KO GYI (1972) conducted an experiment under controlled environment and found that both relative growth rate and net assimilation rate of teak seedlings grown under the photyperiod of 8, 12, and 16 hours were not significantly different. Similarly, KANCHANABURANGURA (1976) found that there were no differences in all growth parameter measured among seedlings of teak grown under the photoperiod of 9.5, 11 and 14 hours.

Geology

Among environmental factors, geology seems to be one of the most important factors controlling the distribution of teak. It is well-known that soils which are derived from different geological formation are normally different in both physical and chemical qualities. Under adverse climatic conditions, soils which are not suitable for growth conditions are likely to inhibit the distribution of the species. Although teak can grow on soils derived from a variety of geological formations such as trap, basalt (dark volcanic rock), gneiss, schist, shale, limestone, granite, sandstones etc., it occurs predominantly and grows best only on soil derived from rocks of volcanic origin, e.g. igneous rocks (trap, basalt etc.), metamorphic rocks (gneiss, schist etc.) and sedimentary rocks (shale, silt-stones etc.), even when the soils where it grows are shallow. In areas where sandstones, conglomerates and laterite are present, the species oppears to be stunted in growth with poor forms and qualities and may be absent (KULKARNI, 1951; PURI, 1951, 1960; BHATIA, 1954; BLOCH 1958; SETH & YADAV, 1959; SAMAPUDDHI, 1963; KOMKRIS *et al.*, 1969). A quantitative study on relationship between geological formation and natural occurrence of teak on the northern slope of Satpuras in India made by KULKARNI (1951) showed that teak is definitely associated with rocks of volcanic origin and it grows better on basic than acidic rocks. KULKARNI (1951) explained that the volcanic rocks usually contained relatively high proportion of some chemical ingradients such as Ca, K, Mg etc. which are required by teak. This explanation was later supported by PURI (1951, 1960), BHATIA (1954) and SETH & YADAV (1959). Figures presented in the Table 3 show the percentage of stocking of teak and non-teak in relation to the geological formation as observed by KULKARNI (1951).

Table 2. Relationship between geological formation pH of soils and distribution of teak.

Geological formation	Average pH value of the resultant soils	Composition of species Teak %	Non-teak %
Deccan trap (volcanic rock)	7.0	80	20
Alluviam	7.0	80	20
Granitic gneisses	7.5	75	25
Calcareous crystalline rock	7.7	60	40
Phyllites and schists	7.2	50	50
Bagra conglomerate	6.8	45	55
Jabalpur conglomerate and haematite	6.5	15	85
Talchirs and Barakars conglomerate		8	92
Bijoris sandstone	6.0	3	97
Pachmarhi sandstone	5.6	0	100
Denwa sandstone	5.5	0	100
Jabalpur sandstone	6.0	0	100

Source : KULKARNI (1951).

Soil pH

Since teak has been known to grow best on soil derived from rocks of volcanic origin such as trap basalt and granitic gneisses, several attempts have been made in systematic studies of soils and geological formations in relation to teak distribution. For example, KULKARNI (1951) found that there were relationships among geological formations, pH value of soil and the percentage stocking of teak in natural forests. This author reported that teak occurred predominantly on soils with pH values ranging from 6.5–7.5. The species was totally absent from natural forests where soils were more acidic than 6.0 pH. On the other hand, on alkaline soils with pH values ranging from 7.5–8.5, teak deteriorates in qualities, and above a pH level of 8.5 the presence of excess alkalies in soils seemed to be definitely toxic toward teak growth. This author also found that soils derived from volcanic rocks such as trap and river alluvia formed from these rocks, to

which the best teak stands in the region were confined, were either nearly neutral or slightly alkaline. Kulkarni's assumption was supported by the work of PURI (1951) and BHATIA (1954). The relationships among geological formations, soil pH and the percentage of stocking of teak in natural forests as observed by KULKARNI (1951) are shown in Table 2.

In contrast to the observation made by KULKARNI (1951), several studies conducted in Thailand showed that the soil which is suitable for teak is generally acidic. The pH values of the top-soils (at the A-horizon) throughout the natural teak forests in Thailand are ranging between 6.2 to 7.0, with an average value of about 6.5 (BLOCH, 1958; SAMAPUDDHI, 1963; KOMKRIS *et al.*, 1969; KEMNARK *et al.*, 1972; BURANAKANOND, 1974). However, this average pH value is still in the range of teak soil pH requirement as proposed by KULKARNI (1951).

Calcium and Other Mineral Elements in Soil

Apart from soil pH, a number of mineral elements content in soil such as Ca, P, K, Mg, N etc. have been found to play an important role in controlling distribution and growth of teak. Several studies showed that teak is a "calcicolous" tree species. It requires a relatively large amount of calcium for its growth and development (PURI & GUPTA, 1950; BHATIA, 1954; PURI, 1960; KAUL, *et al.* 1979) PURI & GUPTA (1950), for example, compared the amount of calcium content in the leaves of teak and sal *(Shorea robusta)* grown under the same site conditions. These authors reported that the amount of calcium content in the teak leaves (2.9% o.d.w.) was almost double that in the sal leaves (1.5% o.d.w.). PURI (1960) disintegrated the ash of teak wood and reported that calcium (CaO), phosphorus (P_2O_5) and silica $(Si0)_2$ were the major constituent of the teak wood ash; i.e. 31.3% for CaO, 29.7% for P_2O_5 and 25.0% for SiO_2. Similarly, KAUL, *et al.* (1979) extracted Ca, Mg, P, K and N from various parts of teak trees grown in the 38-year-old plantation in India and found that Ca was the major mineral content in all parts (i.e. leaves, twigs, live branches, dead-branches stem-bole and bark) of the studied trees. The amounts of Ca, Mg, P, K and N content in the teak trees as reported by Kaul *et al.* (1979) are shown inTable 3.

Table 3. Mineral content in sample teak trees grown in the 35-year-old plantation in India

Sample from tree parts	Mineral content (% o.d.w.)				
	Ca	Mg	P	K	N
Leaves	2.47	0.31	0.18	0.75	1.84
Twigs	1.67	0.15	0.07	0.75	0.42
Live-branches	0.76	0.12	0.04	0.38	0.25
Dead-branches	1.35	0.07	0.02	0.30	0.27
Stem-bole	0.25	0.06	0.08	0.16	0.17
Bark	3.78	0.22	0.08	0.60	0.48

Source: KAUL *et al.*, (1979).

Several attempts have been made to estimate the calcium requirement of teak especially in the plantation. For example, a study conducted at the CTFT (Centre Technique de Forestier Tropical) in Ivory Coast, West Africa showed that the five-year-old teak plantation in Togo required about 108 kg/ha of calcium for its growth and development (ANONI., mimeo., undated). In this report, the teak trees from the five-year-old plantations were harvested and extracted for the amount of CaO content in leaves, bark, branches and wood parts, The consumption of calcium of the teak plantation was estimated and reported as follows:

leaves	71.0	kg of CaO/ha of plantation
bark	23.6	"
branches	9.0	"
wood	4.2	"
Total	107.8	"

Based on this estimation, the CTFT also proposed the model for estimation the teak site quality by using the relationships among the timber production of the plantation, soil depth and the amount of exchangeable bases (especially calcium). That model is as follow:

$$R = \frac{1}{3} PS$$

where R = yield of plantation in m^3/ha; P = depth of soil in decimeter (dm); and S = total exchangeable bases (especially calcium) in milliequivalents.

In relation to geological formation, it has been mentioned earlier that teak thrives on soil derived from rocks of volcanic origin. KULKARNI (1951) and PURI (1951) gave similar explanation that the volcanic rocks usually

consist of a number of minerals such as felspar, hornblende, magnetite etc. These minerals especially hornblende would release a relatively large amount of calcium, phosphorus and some other mineral nutrients, which are required for growth and development of teak, during the processes of decomposition and/or soil formation. The decomposition of felspar also resulted in clayey soils which have a relatively high water holding capacity. Consequently, soils derived from the rocks of volcanic origin were favourable for teak growth and development. This explanation was later supported by the work of BHATIA (1954) who analysed soils of different geological formations for amount of exchangeable calcium and magnesium. Relationships between geological formation, soil pH, amount of exchangeable calcium and magnesium and percentage stocking of teak are shown in the following table.

Table 4. Relationships between geological formations, soil pH, exchangeable calcium and teak distribution.

Geological formation	Soil pH	Exchangeable		Percentage stocking of teak
		CaO	$Mg_2P_2O_7$	
Igneous rocks				*
Decan trap	7.1	0.73	0.32	80
Dykes and sills	6.3	0.50	0.38	–
Granitic gneisses	6.2	0.41	0.28	75
Calcareous crystalline	7.6	0.76	0.54	60
Vindhyan sandstones, shale and conglomerate	6.0	0.37	0.25	–
Quartzites	6.0	0.26	0.25	–
Gondwana sandstones				
Begra conglomerate	6.6	0.37	0.33	45
Jabalpur sandstone	6.0	0.23	0.20	0
Pachmarhi sandstone	5.6	0.24	0.13	0
Alluvium soils				
Calcareous	8.3	2.38	0.33	–
Non-calcareous	8.3	0.56	0.46	–

Sources: BHATIA (1954) cited by PURI (1960).
* KULKARNI (1951).

Apart from calcium and other inorganic mineral elements, organic matter and nitrogen content in soil also play an important part in ecological distribution of teak. A number of studies conducted in Thailand showed that both organic matter and nitrogen content in soils from the teak forests were comparatively higher than those in soils from the nearby dry dipterocarp forests (BLOCH, 1958; SAMAPUDDHI, 1963; KEMNARK *et al.*, 1972). SAMAPUDDHI (1963), for example, reported that the amounts of organic matter content in the top soils from the mixed deciduous with teak. Mixed deciduous without teak and dry dipterocarp forests in northern Thailand were 5.2–6.1, 2.1–2.9 and 0.2–4.0 per cent, respectively. In a study on the estimation of site quality of the teak forest by using the amount of organic matter and nitrogen content in soil as the index, SAHUNALU (1970) found that there was a strong positive relationship between yield of the forest (as determined in term of dry matter production per unit area) and both the amount of organic matter and nitrogen content in soils. That is, the higher content of either organic matter or nitrogen in the soils the greater amount of dry matter production per unit area of the forest.

SUMMARY AND CONCLUSIONS

Teak occurs naturally only in India, Burma, Thailand and Laos. The distribution of this species within these countries is discontinuous. Teak in Indonesia was said to be introduced about 400–600 years ago. There are many factors controlling the distribution and growth of teak. The important factors are rainfall/soil moiture, temperature, light, geological formation or soil parent material and soil conditions. The responses of teak to these individual factors can be summarised as follows:

1. Teak grows much faster under moist than under dry planting conditions. For the production of a good quantity of teak, the moist localities with an average annual rainfall ranging from 1,250 to 2,500 mm, associated with a marked dry period of 3–5 months are the most suitable for plantation establishment of this species.

2. Based on studies under controlled environment, the optimum temperatures for better growth and development of teak are between 27° and 36°C during the day time and between 20° and 30°C during the night time. Under natural conditions, this species grows best in localities which have seasonal fluctuation in temperatures between 13° C (in the coldest month) and 40° C (in the hottest month).

3. Teak is a "light demanding" forest tree species. The range of light intensity of 75–95 per cent of the full day-light appears to be most favourable for growth and development of the species. Photoperiod or day-lenght, especially within the tropical region, was found to have minor effects on growth and development of teak.

4. Geological formation seems to play an important role in controlling the distribution of teak. The most suitable soils are usually derived from rocks of volcanic origin such as trap, basalt, granitic-gneisses. Soils derived from sandstones and quartzites appear to be unsuitable for growth and development of teak.

5. Soil pH is one of the most important factors limiting the distribution of teak. Teak thrives on soils which are neutral or slightly alkaline. The moist favourable soils for growth and distribution of teak are usually having pH between 6.5 and 7.5.

6. Teak is a "calcicolous" tree species. It requires a relatively large amount of calcium in soil for its growth and development. Soil organic matter and soil nitrogen are also important for teak. It was found that the dry matter production of the teak forest is positively correlated with the amount of both organic matter and nitrogen content in soils. Phosphorus and silica are also reported to be contained in a relatively large amount in the teak wood. However, the responses of teak to these two mineral elements are not well documented.

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