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SILVICULTURE AND MANAGEMENT OF TEAK

BULLETIN 24

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By K. Kadambi

School of Forestry

STEPHEN F. AUSTIN STATE UNIVERSITY

NACOGDOCHES, TEXAS

SILVICULTURE AND MANAGEMENT OF TEAK No 24

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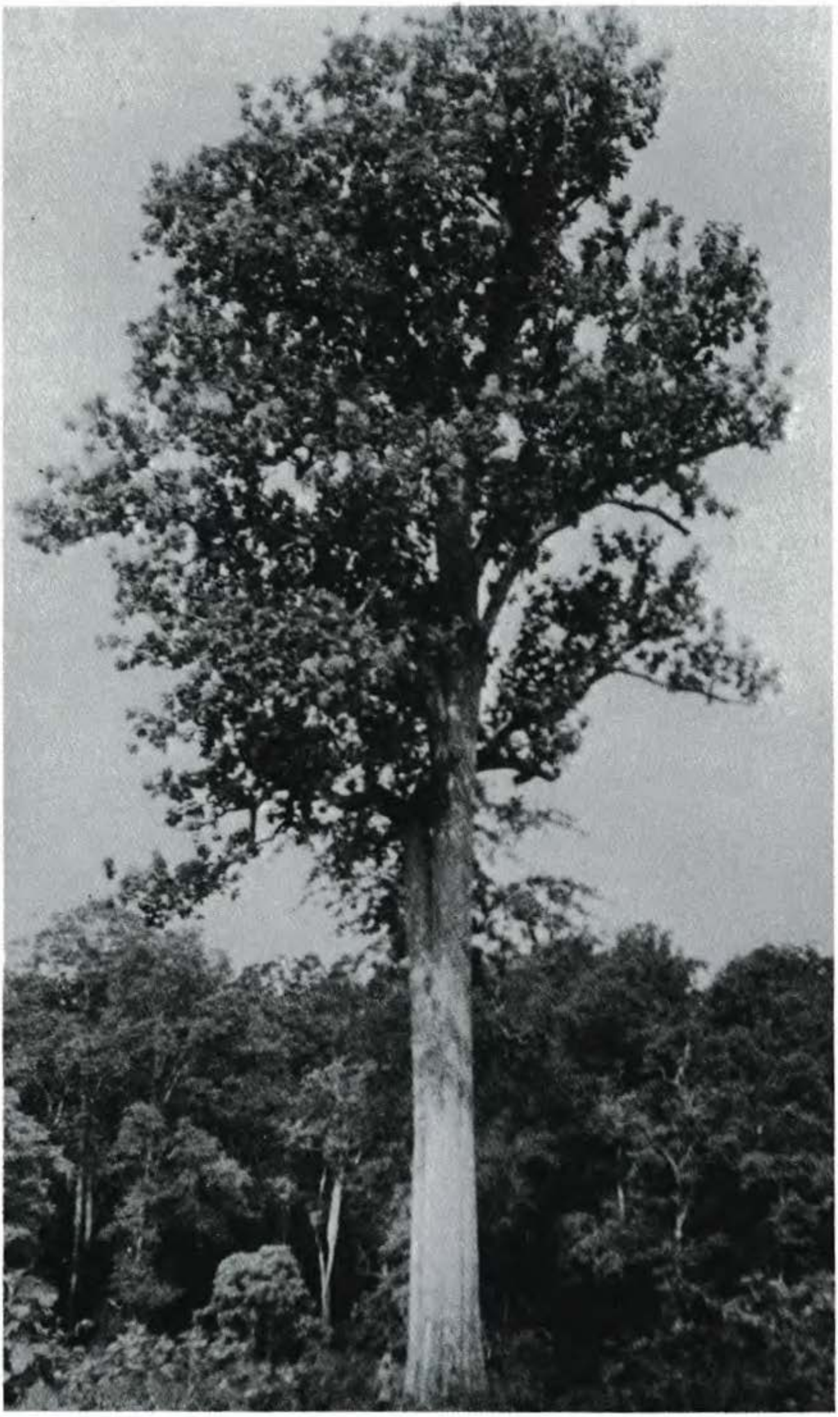

Mature teak tree, height - 133 feet, girth at breast height 19½ feet, natural forest, South Coimbatore Forest Division, Tamil Nadu.
Photo, Forest Research Institute, Dehra Dun.

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INTRODUCTION

Teak is the principal timber tree of Peninsular India, Burma, Indonesia and Thailand and one of the most important timbers of the world. It has been planted extensively in warm climates throughout the world. It is aptly said that "there is virtually no use to which timber can be put for which teak cannot be employed." To ship building, teak primarily owes its centuries old and worldwide reputation. In its home countries, it is the major timber for buildings, bridge and wharf construction, piles, furniture, cabinet work, railcars, wagons, wheel spokes and felloes, and general carpentry.

The reputation of teak timber is due to its matchless combination of qualities—termite, fungus and weather resistance, lightness with strength, attractiveness, workability and seasoning capacity without splitting, cracking, warping or materially altering shape.

The sapwood of teak is white to pale yellowish brown, and heartwood pale brown to dark golden yellow, turning with age to brown, dark brown, chocolate brown (Burma), greenish brown (Thailand) or almost black.

Teak heartwood is generally dull colored, with markings which vary with the locality. It is coarse textured, oily, and characteristically scented when fresh, the odor being sometimes like old leather (Pearson and Brown, 1923).

Seasoned teak is not difficult to saw, though somewhat brittle and liable to chip off at the edges, and is a moderately good turnery wood of the coarser class. It is suitable for carving, though not to a fine style, and can be worked by hand to a good, smooth finish, and fair polish. Teak peels and slices well on presoaking the log in hot water, but it does not glue well. It makes ornamental plywood, but is expensive for general utility work.[1]

A member of the family *Verbenaceae, Tectona grandis* Linn. F., teak is a large deciduous tree which in favorable locations develops a tall, straight, fairly clean cylindrical bole. In age it becomes moderately fluted and buttressed. Its leaves are broadly elliptical and obovate, with blades 12 to 24 inches long (to 36 inches on sprouts), tapering to petioles 1 to 1½ inches long. They have entire margins, occur in whorls, and like those of other species of the genus, are rough above and clothed below with densely stellate, gray or tawny tomentum. Branchlets are quadrangular and channeled, with a large pith.

The white flowers are numerous, and borne in dichotomous cymes of erect terminal panicles 1 to 3 feet long. Campanulate calyx is shortly 5 or 6 lobed, becoming enlarged, bladderlike, reticulate and more or less corrugated in the fruit. Fruit is a hard berry-nut covered with a dense felt of branched hairs. Seeds have 1-3, rarely 4, cells and a central cavity having the appearance of a fifth cell.

[1]Note on the manufacture of plywood in India, Forest Research Institute, Dehra Dun, 1940.

Mechanical Properties of Teak Wood

Teak wood is light to moderately heavy, moderately hard, often somewhat brittle, straight or wavy grained, coarse and uneven-textured. Its figure varies widely; that used for the ornamental purposes is handsomely marked with darker, broad wavy streaks. Growth rings are distinct, with a lighter zone of large pores in the spring-wood. Fernandez (1877,1882) considers that very often more than one ring may be formed in a year. Spurious rings undoubtedly occur but, with some care, they are generally distinguishable from true annual rings.

Weight. For practical purposes the weight of teak timber may be taken at 45 lb. per cu. ft. (Gamble, 1922). The majority of estimates are between 40 and 50 lb., but weights vary widely, the extremes of 31.5 to 55 lb. per cu. ft. have been reported from Burma and Ceylon, respectively. Pearson and Brown (1923) estimated the weight per cubic foot at 12% moisture as 40 lb. for Burma wood, 43 lb. for Malabar wood (Kerala), and 38 lb. for wood from Madhya Pradesh. Two samples of plantation teak wood obtained from Nilambur and tested in Dehra Dun weighed 44 lb. per cu. ft. (moisture 15.3%) and 51 lb. per cu. ft. (moisture 15.7%). The weight of teak wood from Thailand is stated to range from 36 to 43 lb. per cu. ft. at 15% moisture content (Stadelman, 1966, p. 189).

Strength. Strength properties of Malayan teak were reported by Stadelman (1966, p. 53) as follows:

Modulus of rupture, psi	11,440
Modulus of elasticity, psi	1,670
Impact: height of drop, 56 lb. hammer, in.	35
Maximum crushing strength, compression parallel to grain, psi	5,870
Maximum shearing strength, parallel to grain, psi	1,108

It has been alleged that plantation grown teak has less strength than forest teak. Tests at the Forest Research Institute, Dehra Dun, however, do not substantiate this (Table 1). On the whole, there appears to be no marked difference in this respect between natural and plantation grown timber.

In later tests, strength and other properties of plantation teak from Malabar grown under very heavy thinning (Craib's method) were compared with those of teak grown under moderately heavy (D-grade) thinnings, and with natural forest teak from Burma. The results are summarized in Table 2. Timber from trees subjected to Craib's method of advance thinning was found to be equal in strength to other teak timber.

Table 1. Strength of forest and plantation teak from two sources.[1]

Locality and origin of timber	Moisture content, percent	Shear strength, psi	Strength in compression parallel to grain, psi	Transverse strain, psi
Zigon, Burma				
Natural Forest	9.9	1,460	6,751	17,405
Plantation grown	10.8	1,191	8,304	16,397
Nilambur, Kerala				
Natural Forest	20.0	1,933	7,441	13,529
Plantation grown	16.3	2,025	8,276	14,829

[1] Indian Forester, 1912, Vol. XXXVIII, Pp. 126-128.

Table 2. Properties of teak grown in natural forest, and in plantations under moderately heavy and estremely heavy (Craib's) thinning.[1]

	Burma Natural Forest Grown		Malabar Plantation Grown	
	green	air dry	grade D thinning kiln dried	Craib's thinning kiln dried
Specific gravity[2]	.60	.61	.61	.71
Moisture content	51.8	12.0	15.3	15.7
Weight at indicated moisture content, lb. per cu. ft.	57	43	44	51
Radial shrinkage, green to oven dry, percent	2.3	--	--	--
Tangential shrinkage, green to oven dry, percent	4.2	--	--	--
Static bending				
Fiber stress at elastic limit, psi	7,090	10,185	9,700	9,800
Modulus of rupture, psi	11,435	15,135	15,400	17,800
Modulus of elasticity, 1000 psi	1,673	1,877	1,700	1,790
Work to elastic limit, in.-lb. per cu. in.	1.70	3.13	2.98	3.00

Table 2. continued

Impact bending				
Fiber stress at elastic limit	16,745	19,400	18,000	18,100
Maximum drop,[3] in.	35	25	48	64
Modulus of elasticity, 1,000 psi	2,183	2,434	2,020	1,820
Work to elastic limit, in.-lbs. per cu. in.	7.23	8.63	8.93	9.94
Compression parallel to grain				
Fiber stress at elastic limit, psi	4,075	5,950	--	--
Maximum crushing strength, psi	5,870	8,810	7,700	8,350
Modulus of elasticity, 1,000 psi	1,937	2,085	--	--
Compression perpendicular to grain				
Fiber stress at elastic limit, psi	1,055	1,510	1,260	1,820
Hardness[4]				
Radial load, lb.	1,045	1,160	1,380	1,500
Tangential load, lb.	1,030	1,145	1,370	1,630
End load, lb.	915	1,105	1,250	1,390
Shear				
Radial, psi	1,045	1,210	1,400	1,950
Tangential, psi	1,170	1,410	1,340	1,940
Tension				
Radial, psi	525	575	610	--
Tangential, psi	695	680	--	1,180

[1] From Silvicultural Research Report, Madras, 1949-50.
[2] Based on volume as tested, and weight oven dry.
[3] Maximum drop of a 50 lb. hammer causing complete failure.
[4] Load required to imbed a 0.444 inch ball to one-half its diameter.

Fast grown teak, with 1 to 4 growth rings per inch of radius, is weak if light in weight, but is strong if heavy and without gum deposits. Gum deposits increase specific gravity, but reduce strength. Medium grown teak, with 5 to 18 rings per inch of radius is moderately weak if light in weight but strong if heavy. Slow grown teak, with 19 rings per inch of radius, is weak if light in weight but moderately strong if heavy.[2] Boxes made of teak and other timbers tested at the Forest Research Institute, Dehra Dun, showed that boxes of Madhya Pradesh teak were as strong as those of Burma Teak. Fir and spruce boxes were also found to be as strong as Burma Teak boxes of large size.[3]

[2] Report on Forest Administration in Burma, 1934, Pp. 60-61.

[3] Report of the Timber Testing Section, Forest Research Institute, Dehra Dun, 1941.

Seasoning Properties

Teak requires careful seasoning. It seasons well, if slowly, in the log. Trees which have stood girdled before felling for three years contain as much as 30 to 35 percent moisture. If the logs are not converted after felling it takes five to six years before the timber is adequately air-seasoned. Wood fiber contracts considerably in the seasoning process, the radial and tangential contraction in the tests of plantation teak from Nilambur (Kerala) being 2.3% and 4.2% respectively. Shrinkage up to 2.5% in the radial and 5.8% in the tangential directions has been reported. Pearson and Brown (1923) report that in West Chanda division (Maharashtra), teak can be best seasoned by girdling the trees and leaving them standing for two to three years, followed by air seasoning of the lumber for 15 months after sawing. For poles, best results were obtained by felling in August, immersing the poles at once in water for two to three months, followed by air drying for nine months.

Lumber from trees cut in August avoids much of the checking of lumber from trees cut in January and April. Poles cut in January and April and seasoned with or without bark also check badly. Even those cut in August check more than water seasoned poles. These results apply probably to teak grown in the dry zone and seasoned in a locality where temperatures are high from March to June.[4]

In Burma, trees are girdled and allowed to stand for about 3 years before felling; this system produces very good timber. In Thailand, girdled trees are left standing for 2 years before felling (Kaufman, 1968).

On the Malabar coast of Kerala and the Deccan plateau, trees are mostly felled without girdling, and the logs left lying for some time before conversion. If sawed before seasoning, lumber must be suitably stacked and protected from sun and wind to prevent degrade.

Rotary-cut veneers from green timber season quite satisfactorily with a little care, but the green logs must be properly stored, as such logs left in open sun may split from end to end and become valueless.

Durability

Teak is practically proof against fungus and termite attacks, but it is readily attacked by marine borers. It lasts indefinitely under cover; teak samples from the old historic buildings of Vijayanagar (South India), which are over five centuries old,[5] and from Vjjain (Central India), which are even older, were still in an excellent state of preservation. Teak also lasts well in contact with or under water. No artificial preservative treatment is required to prolong its life.

[4]Indian Forest Records, 1919, Vol. VII, No. 1, p. 19.

[5]Indian Forester, Vol. VII, 1880, p. 260.

A chemical analysis of teak wood carried out at Dehra Dun by Dr. H. Warth (Gamble, 1922) gave the following results:

	Percent of dry weight	Percent of total minerals
Soluble potassium and sodium compounds	0.13	16.88
Calcium carbonate and phosphate of iron, etc.	0.31	40.26
Magnesium carbonate	0.21	27.28
Silica, etc.	0.12	15.58
Total	0.77	100.00

Amount of ash in 115 lb. of air dry wood (equal to 100 lb. of steam dry wood) is 0.77 lb.

Calorific Value of Teak Wood

Results of investigations in Java, confirmed at Dehra Dun, have shown that unlike most other woods, the calorific value of the heartwood of Indian and Javanese teak is higher than that of its sapwood.

Calorific values for teak wood have been reported (Rierink, 1938) as follows:

Source	Air Dry Specific Gravity	Calorific value, ovendry Sapwood	Heartwood
		calories per gram	
Thailand	0.63	--	5,218
Burma	0.70	--	5,168
Java	0.67	4,908	5,155
Thailand	--	--	5,244
Burma	--	--	5,155
Java	--	4,927	5,152
India	--	4,870	5,468

Minor Forest Products

Analysis of teak bark from the Pegu region, Burma, has shown that it contains 0.42% of tannin absorbable by chrome hide, 19.38% of soluble nontannins and 80.2% of insoluble matter.[6]

On bruising, leaves of teak yield a red sap sometimes used for dying silk a yellow or olive color. The large leaves are sometimes used as plates for dining purposes, for packing and for making into rough umbrellas or employed as a thatch for temporary huts. Various parts of the tree, including the wood, are used in Indian medicine.

Production of Teak Timber

Accurate production figures are not readily available. Information from various sources, including annual administration reports, not

[6]Indian Tanstuffs and their Tannage, Bulletin No. 1, 1918.

all from the same year, is as follows:

Old Indian States	Approximate Annual Production (cubic feet)
Madya Pradesh	4,800,000
Bombay	1,258,000
Rajpipla	150,000
Mysore	150,000
Coorg	100,000
Madras	900,000
Travancore-Cochin	19,900

From 1960 through 1965, Burma produced annually 15.5 million cubic feet (average) against her estimated annual increment of 25 million. Indonesia averaged from 1956 through 1960 about 3.8 million cubic feet annually, and Thailand in 1959 through 1961, 2.6 million. Average production of Thailand from 1956 through 1966 was 2.5 million cubic feet (Kaufman, 1968).

Since the turn of the century and up to World War II, Burma was the principal teak exporter, accounting for over 75% of all exports followed by Thailand with over 15%, Indonesia about 4%, Indo-China 3½% and India ½%.

In fiscal year 1939-40, Burma exported close to 10 million and Thailand about 2.6 million cubic feet of teak timber. The estimated value of teak exported from Burma was close to $20 million in 1960 and an average of 160,000 cubic feet of logs and 129,400 cubic feet of sawn timber in 1960 and 1961.

India.

In India the range of teak is mainly south of the Narmada and Mahanadi Rivers (lat. about 22°N), but extends north in the central portion to latitude 25°32' N along the Betwa and Dhasan rivers in southern Uttar Pradesh, and to 24°42' in the Aravalli Range of Rajasthan. From these northern limits, teak extends south essentially throughout the peninsula through Andhra Pradesh, Maharashtra, Tamil Nadu, and Mysore, to southern Kerala. Within this broad range, teak occurs on widely scattered tracts, separated by wide areas where teak is absent or only occasional.

Natural teak forms 50 to 80 percent or more of the stocking along the Dhasan and Betwa rivers in Uttar Pradesh. In western Orissa teak occurs on about a hundred square miles bordering Madhya Pradesh. It occurs in both the moist and dry deciduous forests of several districts of Madhya Pradesh including Jubbalpore, Hoshangabad, Seoni, Balaghat, Bilaspur, Gwalior, Indore and Bhopal. In Andhra Pradesh teak is found along the Godavari river and in old Hyderabad state. In Gujarat and Maharashtra, small sized teak extends on trap rock from Surat and Khandesh to the southern limits of Maharashtra. The valuable teak forests of Mysore are in two expansive regions, the northern (about 800 square miles) in Belgaum, Dharwar and North Kanara districts, and the southern (about 1000 square miles) in the districts of Shimoga, Chikmagalur and Mysore. In this state, two teak belts are recognizable, a moister zone to the west with sparse stocking of tall, well formed trees and a drier zone to the east where teak trees are more abundant but of poorer form. In Kerala, important teak forests are found in Malabar and Wynaad districts and on the Anamalai hills. In the Nilambur valley of Kerala is a famous series of teak plantations in alluvial pockets which have been remarkably successful since their beginnings shortly after 1840.

Among the conspicuous associates of teak in peninsular India whose relative abundance varies greatly from locality to locality are *Terminalia tomentosa, T. paniculata, T. belerica and T. chebula, Dalbergia latifolia* (Indian Rosewood), *D. sissoo* (in central India), *Lagerstroemia lanceolata, Grewia tilaefolia, Pterocarpus marsupium, Mitragyne parvifolia, Boswellia serrata* (on dry ridges), *Ougenia dalbergioides* (in central India), *Schleichera trijuga* (Syn. *oleosa*), *Saccopetalum tomemtosum* (rare), *Madhuca latifolia, Cleistanthus collinus* and *Lannea grandis. Anogeissus latifolia* is often very abundant in dry localities but may disappear from moist ones. The bamboos *Bambusa arundinacea* and *Dendrocalamus strictus* are conspicuous associates of teak and influence its management. Rarely, teak grows in assoiciation with sal (*Shorea robusta*), another important timber tree of India, as at Deosana in Bilaspur district, Madhya Pradesh (Fig. 2.)

In the extra-peninsular portions of India and in East Pakistan,

Figure 2. *Sal* (Shorea robusta) *natural regeneration appearing in teak plantation. Haldwani Division, Uttar Pradesh. Teak has shed its leaves in the dry season.*

teak has been planted, more or less extensively, since about 1860, as far north as Dehra Dun (31°N latitude), in Kurseong division of West Bengal, in the Chittagong hills of East Pakistan, and Kulsi and Kamrup divisions of Assam.

Burma.

Important teak zones include the Pegu Yoma hills between the Irawaddy and Sitang rivers, the lower Salween drainage, the drainages of the jhanngyin and Chindwin rivers, and the Upper Irawaddy including the Madaya, Shweli and other tributaries. Other important teak areas are the eastern slopes of the Arakan Yoma range, the hills east of the Sittang River, and the Ataran drainage. As a general rule, teak is scattered singly or in small groups amidst a number of associate species.

Forest types producing teak include the upper and lower moist deciduous, dry deciduous (and their edaphic modifications), the Indaing and semi-Indaing high forests and the moist clay-soil savannah forest. The upper moist deciduous forest is sometimes regarded as the true home of teak.

The main associates of teak include *Terminalia tomentosa, T. belerica* and *T. chebula, Xylia dolabriformis, Pterocarpus macrocarpus* (Burma padauk), *Gmelina arborea, Adina cordifolia,* *Homalium tomentosum, Mitragyne rotundifolia, Careya arborea, Angoeissus acuminata, Cassia fistula* and *Lannea grandis*. In the semi-Indaing high forest of upper and lower Burma, apart from some of the above, teak has *Dipterocarpus tuberculatus, Pentacme suavis, Shorea obtusa* and *Dalbergia cultrata* as associates.

There are several associate bamboos including *Bambusa polymorpha* and *B. tulda, Dendrocalamus membranaceus, D. hamiltonii* and *D. strictus* (the last in dry forest types), *Melocanna bambusoides, Cephalostachyum pergracile, Thyrsostachys oliveri* and others.

In Zigon forest division teak forest covers about one-half of Yoma block. Moist teak type is replaced by dry teak type on the not, southwest and southeast aspects. In moist teak forest teak, *Xylia dolabriformis* and *Bambusa polymospha* predominate. The dry teak forest occurs on exposed ridges and on shale, and here, as in the moist type, *X. dolabriformis* and teak are the principal species, though they do not attain the sizes of moist forest.[7]

In Mansi forest division, the Hwelit forest reserve consists virtually of pure teak of poor quality, and its natural regeneration is very good. The soil is heavy, reddish clay but no pan exists up to a depth of 5 feet.

In the Kyaw and Yawdwin working circles of Yaw forest division, the forest is of the upper moist-deciduous kind, and teak seldom forms a good proportion of trees of the overwood. The forest here is intermediate between the moist type, where teak attains very large sizes, and the dry type where it becomes overmature at low girths. In the north and south Gangaw working circles, teak and *Xylia dolabriformis* are about equally plentiful and *Terminalia tomentosa* more than either. *Pterocarpus macrocarpus* and *Acacia catechu* are also abundant.

Thailand

Teak is found over an area of about eight million acres between latitudes 15°50' and 20°0N and longitudes 97°75' and 101°75' E at altitudes of 300 to 3000 feet. Rainfall ranges from 40 to 60 inches, temperatures from 55° to 100°F. The tree occurs in mixed dediduous forests with their 3 sub-types: upper mixed deciduous, dry upper mixed deciduous, and lower mixed deciduous, teak being most abundant though not attaining the best dimensions but regenerating itself freely. Among important associates of teak are *Pterocarpus macrocarpus, Xylia karri, Lagerstroemia calyculata, Schleichera trijuga, Afzelia xylo arpa, Adina cordifolia, Stephgyne parvifolia, Vitex peduncularis, Garuga pinnata, Tetrameles nudiflora, Bombax insigne, Careya arborea* and species of *Dillenia* and *Sterculia*. Several bamboos occur in the underwood including *Thyrsostachys siamensis, Oxytenanthera albociliata, Bambusa tulda, B. polymorpha, Dendrocalamus membranaceus* and *D.*

[7] Working plan for the Zigon Forest Division, 1923-24 to 1932-33.

strictus.

Teak attains heights of 130 feet and diameters of 2.5 feet under favorable circumstances, in a sound state (Sagreiya, 1957).

Indonesia. Teak occurs in a wild state on the islands of Java and Muna (Van Alphen De Veer, 1957). In Java, teak grows in exceptionally pure stands, often making up 75 to 99 percent of the volume. In forests near Blora, stocking is 95 percent teak, and the percentage of teak is highest on the best soils. The tree attains best development in Java in the monsoon climate of tropical lowlands between sea level and 2,000 feet altitude, with equable temperature (81°F.), annual rainfall of 60 to 100 inches, and a dry season (with less than 3 inches of rain) lasting 3 to 5 months. In regions of heavier rainfall teak is susceptible to attacks of borers. In drier districts growth is considered too poor to be profitable (Becking, 1950).

The commonest associates of teak are *Schleichera trijuga* and, less commonly, *Butea frondosa*. The former is considered the most suitable mixture. The old forests present the appearance of mature woods, with fine groups of natural regeneration of pole and sapling size in open places. The best quality forest reaches heights of 115 to 130 feet. The largest recorded teak tree in 1915 was 147 feet high and 6 feet 8 inches in diameter (Milward, 1915).

Plantings Outside Natural Range

Prior to the late 1800's, efforts to grow teak beyond its natural range were mainly confined to Ceylon and to continental areas now in West and East Pakistan. Since shortly before 1900, teak has been introduced in tropical and near tropical portions of Africa, Central and South America, and in many of the Carribean and oceanic islands.

Ceylon. Teak was introduced in Ceylon by the Dutch and is now found throughout the island at low altitudes. Fairly extensive plantations were established, principally in the dry evergreen forest type in northern and eastern Ceylon, from sea level to an elevation of 1000 feet, where 50 to 75 inches of rain falls annually. Planting was discontinued after 1922 under the impression that large sized timber could not be grown in plantations. Sample plot figures from northern Ceylon show that teak can attain diameters of 12.6 to 14.1 inches in 19 years.[8,9] It should be possible to grow teak of large sizes here, on the richer soils.

Ghana. Teak planting was started in the Togo region about 1905 under the German administration. Remnants of those plantings are found at Yendi, where a few trees have attained heights of 100 feet and diameters exceeding two feet, but their bark has suffered sunscorch on the southwestern aspect. The French continued teak planting after Togoland was divided into British and French

[8] Notes on Exotic Forest Trees in Ceylon, 1935.

[9] Howard, S. H., Exotic Forest Trees in the British Empire, 1932, Oxford.

portions at the end of World War I. The British discontinued systematic planting of teak but introduced it along boundary lines of reserve forests where it is now well established and reproduces itself naturally.

Ivory Coast. A small plantation was opened in 1929 from seed obtained from Togoland where teak had been introduced successfully by the Germans.

Nigeria. Teak has been grown as far north as Zaria, but does well only in the equatorial belt.[10]

Trinidad. Teak was introduced, probably from India, in 1913 and 1915. It is very successful, and free from diseases and pests. The growth and form of trees from Tenasserim (Burma) seed has been found superior. The first plantations were formed by direct sowing, and subsequent ones by taungya (inter-cultivation with agricultural crops).

Jamaica. Teak proved a definite success in river valleys in the parish of Portland, and some astounding growth statistics have been recorded.

Honduras. Teak has been planted in Honduras since 1927 from seed of Burma origin obtained from Trinidad. About 2,370 acres had been planted up by 1955. Because of heavy failures, in some plantations the annual planting was then reduced in favor of cultural operations in existing plantations.

Argentina. Teak was introduced from India in 1929. A few experimental plots are present at the Leandro N. Alem research station in de Misiones province. Planted at a spacing of 2 x 3 meters, at age 17 the trees averaged 6 inches in diameter and 45.5 feet in height.

Ten-year old trees raised from Indian seed in Salta province are reported to have grown well and fruited from the age of six years onward. Close to Oran, in the tobacco area, teak trees on roadside avenues are reported to have good shape.[11]

Moisture and Temperature Relationships

Teak grows best in warm tropical, moderately moist climate on deep, well-drained alluvial soil. In wetter tropical regions, it is replaced by evergreen, broad-leaved forest. It is prominent in dry localities, even where subject to drought and heat. The proportion of

[10] Farm and Forest, 1941, Vol. II, No. 2, p. 76.

[11] Letter, Feb. 4, 1970 from the Director, Servicio Nacional Forestal, Buenos Aires.

teak in the dry forest community decreases with increasing moisture. Depending on the locality, optimum rainfall for teak is 60-80 inches, but it endures rainfall as low as 20 inches and as high as 200 inches. At sea level, rainfall of over 140 inches is detrimental (Foulks, 1895). Although the tree extends into regions of slight frost, the temperature range, over the area in which it is found generally varies from 36 to 118°F. Optimum climates, as along the west coast of India, have temperatures varying between absolute minima of 55° and 62° and maxima of 102° to 110°F.

Aspect also affects teak growth. In dry parts of Madhya Pradesh and on the Deccan tableland, especially on ridges where the soil is shallow, teak vigor is best on cool northern and eastern slopes. Where rainfall is heavier than the optimum, as in parts of Burma, teak prefers the hotter, western and southern aspects, because a dense, wet evergreen forest develops on the cooler northern and eastern aspects.[12]

In Madhya Pradesh, rainfall varies from 30 inches in the west to 60 inches in the east, with local precipitaiton of 200 inches in the Bori valley below the Pachmari hill; 95 percent of all rain falls between mid-June and October, followed by four rainless and three almost rainless months. The groundwater table drops rapidly from December and streams dry up by March.

On the Deccan plateau, 2,000 feet and over, the temperature ranges from 32° to 105°F. but winter frosts in low-lying areas cause considerable injury to saplings and pole size teak. In the plains, temperatures soar to 115°F. by mid-March, but seldom drop below 40° in winter.

In the Ivory Coast, Africa, the year has typically a dry season of five to six months during which teak is more or less leafless. The mean annual temperature at Boadko is 80.6°F., and there is not much variation between the minimum (71.1°F.) and the maximum (89.2°F.). Relative humidity is high. Where savannah type associations occur, the climate is favorable to teak growth.

In Honduras, the climate of teak plantation areas is typically monsoonish with annual rainfalls of 75 to 125 inches, of which 80-90 percent falls between June and January, followed by a season of less rainfall from February to May or early June. In most years no months are entirely rainless. Elevation of most plantation areas is between 50 and 500 feet. Temperatures below 60°F. are rare. The broad-leaved, wet evergreen to moist deciduous forests have been subjected to centuries of shifting cultivation.

[12] Working Plan for the Upper Chindwin Forest Division, Burma, 1937-38 to 1951-52, p.13.

Soils

The teak bearing forests of India are situated largely on hilly and undulating country, though there are very considerable areas on level, well-drained alluvial pockets along rivers. In general, the finest soil for teak growth is well drained, deep alluvium; here the tree attains large dimensions and is sometimes found in highly pure stands. It also grows very well on the fertile, lower slopes of hills where soil is deep. It will not endure stiff soil with inadequate drainage. Even alluvial soil fails to produce quality teak unless well drained.

Teak grows on a variety of geological formations but quality of growth depends on the depth, structure, porosity, drainage, and moisture-holding capacity of the soil. In the Indian peninsula it thrives on the Vindhyan or other sandstones which disintegrate easily, but becomes stunted on quartzite or hard metamorphosed sandstone which weathers slowly. It grows on granite, gneiss, schists and other metamorphic rocks in districts, such as North Kanara, Shimoga and Mysore, and in Malaboar and the Anamalai hills (Kerala). It is found on limestone in parts of Madhya Pradesh and locally in North Kanara (Mysore), and on the extensive trap areas of the Deccan. On shallow soils derived from trap, teak is often of small size but remarkably plentiful; where soils are deeper, as in associated valleys, teak attains fair dimensions. On laterite, even if partly disintegrated, teak is always stunted. Only where laterite is completely disintegrated and mixed with other rocks does teak attain fair size (Troup 1921). Clearfelling the natural moist deciduous forest and replanting the area with a pure crop of teak may accelerate the pace of laterization, because on laterite teak litter disintegrates quickly, and the tree affords inadequate soil cover during summer. At Nilambur, however, analysis of soil under a second rotation crop of teak showed little evidence of laterization.

In Uttar Pradesh, teak prefers deep well-drained, sandy loam, and avoids stiff soils; it is found where such soils overlie gneiss and quartzites. In Assam it grows best on moist loams derived from metamorphic rocks. Similar soils are also preferred in West Bengal.

In Madhya Pradesh, teak is found on a variety of formations--trap, limestone, gneiss, schist, sandstone, conglomerate, shale and clay. On soils overlying trap, teak may form as much as 75 percent of the stand, but is much less abundant on conglomerate or sandstone. In the famous Bori reserve, (Hoshangabad division) excellent growth of teak is confined to the higher reaches of hills with their trap rock, or to recent alluvium derived from trap rock; elsewhere growth on sandstone is poor. Growth is best on soils from basaltic rock because these are able to retain moisture better than soils from crystalline rocks or sandstone. Moisture retentivity of soil is of special significance in Madhya Pradesh with its prolonged break in the monsoon after its first burts (Hewetson, 1937).

Trap soils or alluvium, on which some of the best teak is found, are neutral or slightly alkaline. On acidic soils (pH6) teak is absent, on alkaline ones (pH range 7.5 to 8.5) poor quality teak is present.

Maharashtra

Soils of the Allapalli forest, West Chanda division, have been studied in detail (Kadambi, K. 1959). The rock is chiefly grantite, and the soil shallow light loam on the rocky ridges but deep clay on flat land. Five soil conditions have been distinguished here:

(1) Deep clay (3 feet) with permeable sandstone soil beneath. Here teak is accompanied by *Terminalia tomentosa* and *Stephegyne parvifolia*.

(2) Fine clay-loam of dark grey color underlain with permeable soil of lighter color and soft white sandstone where teak occurs primarily with *Anogeissus latifolia*.

(3) Red murram mixed with fine quartz with sandstone rock or grey soil beneath where *Xylia xylocarpa* is the chief associate of teak.

(4) Deep, often profileless alluvium, often with a very high proportion of sand, on which teak tends to occur in pure stands where the soil is not too sandy.

(5) Sand overlying clay, from which teak is absent.

On the first two soils listed teak appears to contradict the belief that the tree cannot thrive on clay, but examination reveals that the root system of teak lies embedded in the pulverized sandstone enriched by particles from above. The teak seedling starts its life on clay, but its shoot dies back seasonally for a number of years. A strong root system develops and enters the fertile, more or less perennially moist sub-soil, and puts out a powerful upright shoot that survives the seasons of drought and cold. When rains start, the heavily cracked clay lets in water to the fertile subsoil which it also seals off from evaporation during the long dry season.

In the Panch Mahals of Gujarat and Maharashtra, and the North Kanara forests of Mysore the teak bearing soils are deep, fertile loams formed from gneiss, schist, sandstone and quartzite; elsewhere in Gujarat and Maharashtra it occurs on trap. Laterite is common in Mysore but teak avoids it.

In Andhra Pradesh, Tamil Nadu, and Southern Mysore, the rocks underlying teak areas are granites and gneisses. The teak soils of Andhra Pradesh are red, black and mixed, and the tree attains fair sizes on the first, if deep and well drained. These soils have high percentage of calcium, especially in the B layer.[13,14] Good teak grows also on alluvial terraces of the Godavari river (Table 3). In Shimoga and Sagar divisions (old Mysore) teak grows on fine loam

[13] Working Plan for the Godavari Lower Forest Division, 1936-1965.

[14] Working Plan for the Bori Valley Forests, 1950-1960.

Table 3. Analysis of soil samples from teak bearing alluvial terrace, upper Godavari river [1]

Description	Pit No. 1 [2]		Pit No. 2 [3]		
	A Layer 0-1½ in.	B Layer 1½-10½in.	A Layer 0-1½ in.	B Layer 1½-12 in.	C Layer 12-24 in.
Textural class	Sandy	Loam	Sandy clay loam	Sandy clay	Sandy loam
Stones & gravels (above 2 mm.) percent of total weight	1.4	3.58	7.24	13.21	5.63
Sand, percent of screened fraction	58.45	64.57	53.52	47.68	61.21
Fine sand, percent of screened fraction	20.52	13.29	12.74	12.01	16.83
Silt, percent of screened fraction	4.85	5.65	8.15	7.15	3.65
Clay, percent of screened fraction	12.45	12.25	19.15	26.65	13.55
Organic matter (loss on ignition) percent of screened fraction	2.79	2.75	2.36	1.90	1.65
Moisture (in air dry soil) percent of screened fraction	1.26	1.88	2.75	3.36	2.14
Calcium carbonate, percent of screened fraction	0.04	0.05	0.13	2.59	1.48
Loss by solution (N/1 HCL), percent of screened fraction	0.47	0.59	1.43	1.00	0.99
Total Nitrogen, percent of screened fraction	00.067	00.035	00.026	00.012	00.008
Available P_2O_5, percent of screened fraction	00.025	00.007	00.002	00.002	00.002
Available K_2O, percent of screened fraction	00.011	00.007	00.007	00.006	00.005
SiO_2O_3 ratio, in clay, molecular ratio	2.47	2.50	2.61	2.73	3.15
pH value (1.5 suspension)	6.7	6.4	7.1	8.0	8.0
Total exchangeable bases, milli-equivalents	6.39	6.29	13.20	16.40	11.14
Exchangeable Ca, milli-equivalents	5.28	5.33	7.01	6.40	4.03
Exchangeable K and Na, milli-equivalents	0.31	0.31	2.22	5.90	3.71
Exchangeable Mg, milli-equivalents	0.80	0.65	3.97	4.10	3.40

[1] Working plan for the Godavari Forest Division, 1934-1944.
[2] Local soil name, "Sundra Boru."
[3] Local soil name "Lanka."

weathered from granite and schists, and on fine gravel from laterite.[15,16]

In Mysore division, teak occurs on a clayey, black deep soil mixed with nodular limestone and on a pale grey or red soil of varying tenacity.[17] In other outlying areas of the State (e.g. on Devarayadurga hill), teak is found on shallow, rocky poor soils from trap rock.[18] In Tamil Nadu teak grows at the foot of the Eastern Ghat hills on the deep red loam, probably of alluvial origin from the mountain flanks.

Kerala

In the Nilambur forest division, home of the celebrated teak plantations, the underlying rock is granitic gneiss. Distribution of the laterite is extensive. Throughout the area there are intrusive veins of quartz.

Granitic gneiss disintregrates into loam, shallow and stony on ridges, deep and fine in valleys. The laterite is found in varying degrees of disintegration, from hard rock to fine gravel. Along streams geeiss or the laterite is overlain by alluvium, often very deep, and usually containing pebbles and boulders of quartz and gneiss. Near hillocks and in the plains river alluvium is overlain by laterite alluvium. In low-lying localities liable to inundation, soils are superimposed with very fine clayey silt, ofter a few inches thick. Under pure teak, humus varies in depth, fairly deep in virgin forests, relatively shallow in other areas.

The primary factors affecting growth are soil drainage and depth. Poor drainage results in bad soil aeration in a locality with heavy rainfall as in Nilambur (about 150 inches annually). Given good drainage and depth, river alluvium or loam produces the finest teak growth. Within a few yards a forest of magnificent growth may change to one of very poor growth. This may be caused by poor soil drainage or by the presence of laterite (Bourne, 1922).

In the Nilambur plantations, teak attains best growth and quality on level but well drained, deep alluvium with little profile development, which is found near river banks. Such soils are perpetually moist but not wet (Davis, 1940), and there is little leaching; they are therefore comparatively stable and have not deteriorated under second rotation teak.

On unstable, sloping soils away from rivers, growing of a light demanding species like teak, after clearfelling and burning, accelerates erosion and laterization. The soil thus loses its power to retain moisture, and *Xylia xylocarpa* tends to replace teak.

Griffith and Guptha (1947), who investigated laterization of teak soils, concluded that the molecular ratio of silica to sesquioxides

15 Working Plan for the Shankar and Sakrebyle Forests, Shimoga Division, Mysore, 1933-42.

16 Working Plan for the forests adjoining the Sagar-Anandapuram Railway, Sagar Division, Mysore, 1943-52.

17 Working plan for the Metikuppe, Kakankote, etc. group of forests, Mysore Division, 1941-61. Superintendent, Government press, Bangalore, 1945.

18 Working plan for the Devarayadurga group of forests, Tumkur District, Mysore, 1942-51.

(oxides of iron and aluminum) provides an indication of the suitability of soil for teak unless some factor such as a laterite under a shallow soil, excessive boulders or high water table (3-4 feet in winter) intervenes. Under swampy conditions teak is replaced by *Lagerstroemia flos-reginae,* while on shallow laterite soil *Xylia* predominates. Hilltop topography is most unfavorable to teak while a northerly cool aspect and alluvial sites at the foot of hills are most advantageous.

The following helpful factors are generally responsible for the high quality of teak in Nilambur valley:

(1) High SiO_2/R_2O_3 ratio in the soil.

(2) Alluvial site and consequently helpful, cool locality.

(3) High content of bases, especially Ca and Mg in the soil.

(4) Good moisture availability due to appropriate water table.

(5) Good sand and loam texture and consequent good soil-mass drainage.

(6) Good regional drainage.

Burma

Teak occurs on geological formations and soils in Burma as follows:

Rocks and Soils	Locality and Comments
Granite, gneiss, schists and other metamorphic rocks	Hills east of the Sittang river, parts of the Ruby Mines district and the Madhya drainage
Soft tertiary sandstone and shales, with sandy loam to deep, well drained clayey loam	Pegu Yoma hill range, parts of Chindwin drainage (good growth up to 2,500 feet altitude where sandstone soil extends below the root zone; poor growth between 2,500 and 3,000 feet where sandstone outcrops, teak absent above 3,000 feet)
Recent alluvium	Throughout the teak zone of Burma, sometimes in near pure stands, on well drained alluvium.
Laterite	Teak is sometimes found on laterite but is invariably stunted.
Limestone rock disintegrated	Thaungyin Valley, Madaya Valley and parts of Chindwin drainage; growth is good if loam is deep, stunted if limestone is hard and soil shallow.

According to Barrington[19] the following applies to Burma soils:

1. Teak will not survive to maturity on heavy soils unless they are calcareous.

[19] H. H. M. Barrington, Inspection Notes, 1921.

2. First-rate growth can be expected on well drained alluvium if not too heavy, and on heavy, calcareous soils in dry mixed forest.
3. Second-and third-rate teak can grow on lighter soils in dry, mixed forests, whether or not they are calcareous.
4. Only stunted teak can be expected on heavy, calcareous soils bearing scrub.

Thailand

In the highlands of northwest Thailand, teak is found between elevations of 650 and 2500 teet; at higher altitudes it is replaced by sub-tropical evergreen or coniferous forest.

The underlying rock in the teak zone is granite, intruded by basalt, diorites, gneiss, schist and quartz. Teak occurs on the ranges of narrow limestone hills which occur throughout the teak zone, but avoids the large areas of laterite.

In well-drained, alluvial valleys teak attains its best dimensions. Elsewhere, teak grows on soils developed from granite, sandstone and limestone formations, flourishing best perhaps on limestone formations (Banijbhatana, 1957).

Lime Requirements of Teak

Opinions are divided on this subject; (Hamilton, 1930) connects the patchy distribution of teak in certain areas to occurrence of lime, teak being absent if lime is absent. In Pegu and Arakan Yoma hill ranges and west of the Irawaddy River, teak is invariably found where gypsum or limestone occur embedded or interbedded in the clay. On sandstone, teak is found where particles of silica are cemented together by lime, and Hamilton contends that even on fertile alluvium, teak of best quality can only be grown in places where leached lime is redeposited. Kadambi (1940) has noticed in Jaugar Valley, Mysore, that teak-bearing soil contained a small quantity of lime, while lime was practically absent where teak does not occur. Although it is not possible to conclude that the existence of teak depends upon this extra lime, soil analysis showed that the two soils are practically identical in all other respects.

Laurie (1931), at Paladakadavu in the Anamalai hills of south India, found no significant difference in lime, phosphoric acid, potash content nor in acidity between soils with and without teak; both soils were uniformly acid and markedly deficient in lime as judged by agricultural standards.

The result of soil analysis is in the following table:

	Teak Areas				Non-Teak Areas			
	Locality A		Locality B		Locality A		Locality B	
	Surface soil	Deep soil	Surface soil	Deep soil	Surface soil	Deep soil	Surface soil	Deep soil
Lime (CaO), percent	0.103	0.130	0.385	0.180	0.286	0.077	0.127	0.100
Total Phosphoric acid (P_2O_5), percent	0.088	0.070	0.090	0.071	0.141	0.121	0.075	0.037
Total Potash (K_2O), percent	0.258	0.366	0.233	0.219	0.241	0.281	0.132	0.260
pH (Quinkydrone method	4.940	4.990	6.490	5.820	6.580	5.590	5.240	5.310

Teak grown in Palakadavu Valley is exceptionally fine, developing to large sizes with clean, cylindrical bole, although growing on a slightly acidic soil which is deficient in lime.

In Java, although teak grows predominantly on tertiary lime and marl formations, good teak forests are also found on soils of volcanic origin with low lime content. Teak of top qualities occurs also on soils of calcareous origin from which all lime has been leached out. Teak is not fastidious with regard to chemical constituents of the soil; possibly it is excluded from the more favorable red soils (of volcanic lime origin) by competition of other indigenous species.

Research on Java teak soils has indicated that it is not the physical (actual) lime content that affects teak growth but that physiological lime is important. High lime content occurs in bad teak soils. Water solubility of lime varies according to the size of its particles and their origin. Only lime found in a state of fine distribution around the smallest soil particles can influence growth of teak.

The rock formation of teak plantation areas of the Ivory Coast consists of schists, quartzites, dolerites, or granite rocks with undulating topography and capping of laterite. Decomposition of granite results in red soils with ferruginous concretions or with well areated soils favorable to teak.

SILVICULTURAL CHARACTERS

Development of Trees and Stands

Size

Under favorable conditions teak attains large dimensions in a sound state. From Thailand has been reported a tree, claimed to be the world's largest (1965), approximately 22 feet in diameter at breast height and 151 feet high. Records of other large trees in India and Burma are as below:

Place of Occurrence	Diameter feet	Height feet	Remarks
India			
Travancore, Kerala	7.0 (at butt) 2.2 (at 70 ft)		Bourdillon (1895)
Anamalais, Kerala	7.0 plus	80-90 (to first branch)	
Edakutha forest, Malabar	5.0	192	Venkataramana Iyer (1913)
South Coorg, Mysore	8.0	—	Yielded 3 logs of 562 cu. ft., the first of diameter 6 ft; (Tireman, 1918)
Tekkadi leased forest Coimbatore	6.0	—	Yielded 11 logs of 711 cu. ft. (Habibulla Saheb, 1918)
Paladekadava, South Coimbatore	—	—	Yielded 5 logs of 1099 cu. ft., (Wimbush, 1920)
Burma			
Gwethe forest, Toungoo	5.11 (6 ft. from ground level)	114 (clear bole)	(Troup, 1921)
Myttha-Paulaung Forest	6.4 (6 ft. from ground level)	—	60 ft. clear bole (Troup, 1921).
	5½	192	116 ft. to first main branch (Troup, 1921).
Mohnyin forest, Katha	3-3.2	152	93 ft. clear bole (Troup, 1921).

Phenology

Leaves. Teak is mostly leafless in the dry season. Depending upon the moisture available to the tree, the leafless period varies among localities, with the moisture retentivity of the soil, and with the rainfall and its distribution. Leaf-fall thus varies from year to year, and with the situation of individual trees or stands. Two identical trees standing close to each other on the bank of Tunga River at Sakrebail, Mysore, varied by three weeks in leafless period, owing to differing moisture holding capacity of the soil. Inheritance may also play its part in determining the length of the leafless period. Over the greater part of India and Burma, in dry situations, teak leaves are shed from November to January or February and, as a general rule, trees are leafless during the greater part of the dry season. New leaves begin to appear from mid-March to June. Chauhuri (1930) has shown that there is no cambial activity in the trunk of teak trees when branches show no signs of foliar development.

The following phenological data on leaves are available:

		Leaf-fall		Leafing	
Location	Period	Beginning	Completion	Bud Unfolding	Completion
Dehra Dun	1928-41	Mar. 23	May 15	May 16	July 13
Uttar Pradesh	1930-40	Mar. 23	May 7	May 36	June 17
Orissa	1938-43	Jan. 8	Feb. 11	Mar. 30	June 17
Bengal	1935-42	Feb. 15	Apr. 9	Apr. 27	May 23
Madhya Pradesh	1935-36	Dec. 7	Apr. 8	Apr. 30	June 19
North Kanara (Mysore)	1936-43	Jan. 9	Mar. 13	May 30	June 28
Malabar (Kerala)	1936-41	Dec. 28	Mar. 1	Mar. 23	Apr. 26
Average of all localities		Jan. 28	Mar. 31	Apr. 30	June 12

In Honduras, Central America, a more or less similar pattern prevails. Leaves begin to fall at the onset of the dry season, in February; leaf-fall is maximum in April-May. Leaves reappear at the beginning of the rains in June or July, and trees are in full leaf by mid-August. Shedding intensity may vary from year to year, from locality to locality and from tree to tree.

Flowers. The large terminal panicles of white flowers begin to open in June-July, (May in Nilambur, Kerala) and trees are at their height of flowering in July-August. End of flowering is in August-September (July in Nilambur) according to the locality and season. In abnormally wet seasons flowers may begin to appear earlier than usual. Dates for flowering stages are as follows:

Locality	Beginning of Opening	Maximum Flowering	End of Flowering
Dehra Dun	Aug. 9	Aug. 27	Sept. 27
Uttar Pradesh	July 21	Aug. 12	Aug. 27
Orissa	July 26	Aug. 17	Sept. 4
Bengal	July 8	Aug. 2	Aug. 25
Madhya Pradesh	July 6	July 27	Aug. 18
Bombay	July 9	July 20	Sept. 3
Madras	May 20	July 5	July 23

Teak has been observed in full flower in Tirunalveli district, Tamil Nadu, in January 1915 (Troup, 1921) but this is exceptional. There is no definite information as to how the teak flower is fertilized; small bees and other insects are probably concerned, but we do not yet know exactly which they are.[20]

Teak starts flowering fairly early in its life, and instances are on record of teak plants bearing flowers when a few months old. As regards this, two different phenomena have to be distinguished:

(1) Occasional, precocious flowering of a very young plant in a plantation. This is probably an abnormality.

(2) Regular flowering at an unusually early age.

There is no experimental evidence that early flowering is necessarily connected with unfavorable local factors, though this is the general belief.

At the Forest Research Institute, Dehra Dun, India, a stump plant planted in 1928 flowered in 1932 and produced only 3 seeds. The flowering branch dried up over a length of 2 feet from its tip. A teak tree grown from seed sown in 1911 or 1912, flowered in 1918, an unusually dry year, but bore no fruit. In Buxa and Chittagong divisions (East Pakistan) a few trees commenced flowering in plantations 6 to 9 years old. In Assam, three-year old teak flowered in Sylhet and Nowgong divisions. R. N. De has reported that in plantations formed in localities where evergreen species originally existed teak has flowered often within 3 to 4 years of the planting.[21]

The following records of early flowering of teak in Orissa, by D. H. Khan, are available:

Forest Division	Locality	Age of Plantation (years)	Height of dominant flowered trees (feet)
Russelkonda	Ravine	3	15
Angul	Raigoda Compt. 6	7	55
Angul	Tarva Compt. 10	6	50

[20] Indian Forester, May 1946, p. 226.
[21] Indian Forester, Sept. 1960, p. 564.

Flowering is generally good every year. In Bhandara division of Maharashtra, in 1938, a fairly general flowering occurred in a 9-year old (30 feet high) plantation on a good quality site. Early flowering has been recorded of a plant, (raised from seed), a few months old, about 10 inches high, and with a flowering shoot about 12 inches long. The plant flowered next year also, when 18 months old. Other cases of early flowering reported include those of G. C. Robinson[23] in Lower Godavari Division of Andhra Pradesh, of 2-3 year old teak plants, and S. A. Davar[24] in Gollapalli Reserve of old Bastar state, of coppice shoots, at age 4 years and 9 months.

In 1938, a general flowering occurred in south Burma plantations 18 to 27 years old. This was not accompanied by any marked falling off in the rate of growth. A teak plant 23 inches high and 2½ inches in girth at base, in the nursery of the Burma forest school at Pyinmana, (introduced from Katha division 3 years earlier) bore flowers and fruits every year.[25] Maung Theni Lwin reported a seedling of 5-6 months, 5 feet high, 3 inches in girth at the base, which produced 17 pairs of leaves with 5 flowering panicles in December instead of in the usual rainy season.

Flowering in Honduras begins at the end of August, as in southeast Asia, with white, insect pollinated masses of flowers. Teak is both self and cross pollinated (Coster, 1933) and as in India, isolated trees produce fertile seed.

Fruits. Teak fruits ripen and fall from November to January, but some remain on the tree well into the hot season. The following phenological observations are on record:

Locality	First ripe fruit	Most or all fruit ripe	First fruit falls	Most fruits fallen	All good fruits fallen
Dehra Dun	Dec. 19	Feb. 8	Jan. 28	Mar. 8	Apr. 27
Uttar Pradesh	Nov. 17	Jan. 28	Feb. 11	Apr. 25	May 15
Orissa	Nov. 5	Dec. 16	Dec. 26	Jan. 15	Feb. 23
Bengal	Sept. 9	Feb. 4	Mar. 17	Mar. 2	Mar. 11
Madhya Pradesh	Sept. 22	Jan. 12	Feb. 8	Mar. 14	Mar. 11
Bombay	Nov. 12	Dec. 15	Dec. 27	Feb. 14	Feb. 27
Madras	Oct. 19	Dec. 1	Jan. 19	Mar. 7	Mar. 16

Root Development

On deep loam a taproot is developed early and well, and this probably is the main water supplying root. In older trees, the taproot though long, is not very thick. In water-logged alluvial soils and in

[22] Indian Forester, May 1935, p. 343.
[23] G. C. Robinson, Inspection Notes, Mangalore North Division, 1931.
[24] S. A. Davar, Silvicult. Ledger Files, 1934.
[25] Indian Forester, Jan. 1923, p. 28.

clay, roots are stunted and the taproot very poorly developed. The water supply in the soil has an intimate effect on the area of fine water absorbing rootlets and their distribution throughout the soil mass (Castens 1922).

The following observations on root development in Honduras have been recorded by Schubert (1959): At 6 months, seedlings grown in shade had a single taproot 6.5 inches long, and laterals of equal length, and a shoot 7 inches long. Those grown in the open had shoots 5 feet long, and one or two taproots, 12 inches long, with laterals of equal length but thin and located close to the ground surface.

At 1½ years, plants, grown from stumps [26] with 2 to 3 inch shoots and 8 to 12 inch roots, and dug up 11 months after planting, had one large vertical root 12 inches long with additional vertical roots emerging from its bottom and sides. Lateral roots were up to 5 feet long, some spreading just below ground level, but with others penetrating into the soil.

At 2½ years transplants in the nursery had vertical roots, often forked, 2½ feet long, with thin lateral roots of equal length.

At 3½ years plants which had not been transplanted had no identifiable single taproots, these being replaced by a number of verticals and/or laterals.

At 7-8 years, seedlings at 6x6, 8x8 and 10x10 foot spacing had a vertical and a lateral set of roots. Verticals were developed best in the 6x6 spacing and most verticals emerged directly beneath the stem, but in the 10x10 spacing they emerged from the lower side of the laterals. The laterals had maximum spread, depth and development in the 10x10 spacing.

Heartwood

Ferguson (1934) has shown that for the same stem diameter, sapwood is wider with increasing rate of growth (improving site quality) of the tree, and as the stem sections are located higher up the stem. The age at which heartwood appears in a tree varies among stands, the start of heartwood being always introduced by wounds caused by thinnings, cleanings, insects, etc. This is probably a reason why the age at which heartwood appears varies in different stands.

Tolerance

Light

Teak is a pronounced light-demander, intolerant of shade and requiring complete overhead light. Its crown requires freedom on all

[26] Stumps "are seedlings after 1 growing season in the nursery, prepared for outplanting by pruning off the shoots at 1 to 2 inches, and the roots at 6 to 8 inches." See Artificial Regeneration.

sides for proper development. However, in very hot and dry areas, teak seedlings and young saplings benefit by protection against the hot afternoon sun. In Madhya Pradesh, teak saplings are found in the shade of bamboos, but their growth is very slow, and they shoot up normally only on removal of bamboos and overwood, restoring full overhead light. Leading shoots of teak are very intolerant of the whipping action of bamboos or interfering trees.

Root Competition

Teak is very sensitive to mutual root competition. For this reason in Java, it is essential to separate neighboring stands of teak by isolating ditches about 20 inches deep and wide. The ditches must remain open; otherwise roots would quickly grow across them and adversely affect the growth of teak along the edge. (Becking 1950). Trenching experiments in Coorg, India, to determine effect of root competition from adjoining forest growth on teak planted in a clearfelled area indicated that trenching is advantageous.[27] In Java, Coster (1933) showed by trenching between an old and a young teak plantation, (each trench being 25 yards long, 2½ feet deep with intermediate untrenched strips) that in trenched plots teak plants grow well almost to the edge of the old crop; in untrenched plots many plants die in the corresponding edge strip, and development of survivors is backward both in height and diameter. Growth of teak, particularly in diameter, is also adversely influenced by intermixing or underplanting teak. Coster (1933) reported that shallow rooted understory species are more harmful to teak than deep rooted ones. Bamboos are thus harmful, while *Leucaena* which is deep rooted, is less so. Fertile soils which have thick undergrowth hamper the growth of teak if rigidly protected from fire. Natural regeneration of teak in Java succeeds only on good soils reasonably free from weed growth. Regeneration along irregular edges will fail unless trenched.

Weeds

Teak seedlings are very sensitive to suppression by weeds; they cannot survive without repeated weedings. Experiments at Dehra Dun involving two parallel lines of teak seedlins of which one was regularly weeded and the other was nit, resulted in the death of the latter. Such death may not be due to suppression from weeds alone; there may be other unfavorable factors like: (1) rot setting in amidst damp weeds, (2) drip from overhead trees, (3) elimination of oxygen from the root system of teak by the weed cover on the soil, and (4) root competition.

[27] Coorg Research Ranger's Report, 1936.

Sensitivity to Climatic Hazards

Frost

Teak is tender to frost but it has such remarkable powers of coppicing that if a frostbitten plant is cut back, it may send up an enormous shoot which often gets above frost level and survives. Though over most of its natural habitat frosts are unknown, abnormal frosts which occur occasionally towards the northern limits of the distribution of teak kill back poles to ground level. In parts of central India natural teak regeneration is unable to make headway on lowlands along streams owing to frost damage. Teak seedlings may die of frost injuries in the first year of life. In subsequent years, frost bites back the shoots but does not generally kill the plants.

Drought

In years of abnormal drought teak suffers severely, but normally it is remarkably hardy; it grows on some very dry hills of the Deccan Plateau, but reaches only small size.

In their first year teak seedlings are sensitive to drought. This is a common cause of first season mortality, expecially among late germinated seedlings, whose roots have not penetrated to persistent moisture. In dry localities, tops of seedlings may die back in successive dry seasons while the root develops, eventually becoming vigorous enough to produce a stem that can survive. Very young seedlings cannot tolerate planting after pruning of root and shoot, but survival approaches 100 percent for seedlings pruned and planted at about 1 year of age.

Resistance to Damaging Agencies

Wind

Teak is a wind-firm tree owing to its well developed taproot or subsidiary root system.

Fire

Teak has remarkable fire resisting power. In the moist deciduous forests of India which are subjected to annual fires, much of the hollowness of the boles found is probably due to fire. However, in some cases, fire encourages teak regeneration by destroying its less fire-resistant competitors. Smales (1917) has recorded that in fire protected areas of Burma, most natural teak seedlings were weak and variously deformed while in unprotected forests such shoots had been burnt back and replaced by vigorous ones. In Burma, a burning experiment in a young crop of teak with bamboo between 1900 and 1908 resulted in the almost complete removal of bamboo and, compared to the unburned plot, there was 43 per cent more girth increment of teak trees in the burned plot; though not conclusive, this experiment indicates the beneficial effect of fire in moist teak forests.

In Madhya Pradesh, which has a prolonged annual dry season, in unprotected localities teak trees suffer damage from fire year after year. Ground fires also kill the overground portions of teak seedlings, though these are less easily killed than seedlings of several other tree species in the same forests. The rootstock of teak is fire resistant, enabling the tree to survive on fire lines recleared and burnt annually, or in overgrazed places or those under shifting cultiviation.

In regeneration areas generally closed to grazing, grass growth after one or two years is very dense, and a fire in such an area increases the proportion of the fire-hardy teak relative to other species.[28]

Young teak plants have remarkable power of recovery from fire; their shoots may be burnt back every year but the root system survives and gets successively stronger and finally produces a permanent shoot which survives a fire. Shoots emerging from the rootstock after a fire are generally more vigorous than the old ones, and this stimulating action of fire has occasionally been used to improve backward plantations by allowing a low fire to run through them and cutting back the plants immediately thereafter, an operation called "fire coppicing".

Experiments in Coorg, (Mysore) and in Burma[29] on burning a plantation in its second year have indicated that the burning is advantageous: (1) it improved growth of teak, (2) plants in the burned portion required fewer weedings and weeding costs were lowered, (3) teak growth was more uniform, (4) a mixture of timbers and superior type of undergrowth appeared.[30] Similarly, in Burma, burning in a two-year-old plantation showed that: (1) the number of weedings required was reduced from 2 to 1, (2) height growth of seedlings in the April burnt plot was better than in the unburnt plot.

Grazing

Teak is not as readily browsed or grazed as most of its associate species. Heavy grazing is, however, harmful to teak in areas under regeneration because its young shoots, though not readily browsed, are soft and easily broken or trampled by cattle.

Other Mammals

Teak suffers from injury by various mammals. In parts of southern India rats sometimes gnaw the roots of young plants, pigs root up seedlings, and sambhur deer, axis deer, and bisons *Bos sondaicus* (saing) of Burma and *B. gaprus* (kati) of India strip off the bark and kill teak. The worst offender is, however, the elephant, which often ruins teak plantations in parts of Malibar and Mysore districts, and in Burma.

[28] Indian Forester 1941, pp. 22-23.
[29] Indian Forester, June 1922.
[30] M. V. Laurie, Tour Notes, 1940.

Insects

Teak suffers from epidemic attacks of defoliators, the commonest among them being *Hybloea puera* Cram and *Hapalia macheralis* Wlk. The "teak leaf roller" - *Pahger damasteasalis* Moore, though not so widespread as the above, does considerable damage on dry hill slopes. Teak borers cause serious injury in Burma, the most serious being the larvae of the moth, *Dnomitus ceramans* Wlk., which bore large holes in standing trees. Another borer, *Cossus cadambae* Moore, does much damage in Travancore, Kerala, by tunneling down the pith of 1 to 2-year old plants which have to be cut back; it also enters trees through wounds caused by the lopping of branches.

Teak also is attacked by gall-forming insects in some localities especially on unsuitalbe sites.

Mistletoe

Loranthus, an epiphytic flowering plant is a common parasite of teak in many areas, damaging the crowns of trees beyond the sapling stage, and reducing their rate of growth.

Fungi

In general, teak does not suffer from serious fungus disease.

Abnormalities

Various abnormalities are on record in the development and arrangement of teak leaves, like alternate leaves with double mid-rib both of which are placed on one side, leaves normal but placed in a spiral or alternately, and the like. In one instance a case of fusion of two leaves into one, forming a double leaf, has been found.

E. O. Sampsar has recorded the following abnormal teak plant found in a teak platatin in Dangs Division, Gujarat. Raised from a stump it attained in seven months a height of 5 feet 6 inches. The stem was zig zag and the leaves, at first alternate, later became opposite. A somewhat similar case was reported by D. E. B. Manning from Burma.[31]

Teak Races and Seed Origin

Teak trees from different parts of India or Burma can be distinguished from one another by morphological peculiarities which are heritable. These "races" differ *inter se* in fruit and seed size, shape, color, texture, size, and covering of the leaves, weight and germinative capacity of seeds, rates of growth, disposition of branching, fluting and cylindricity of boles, figure and quality of

[31] Indian Forester, Nov. 1931.

timber, resistance to external dangers like frost and drought and oxygen deficiency in soil and others (Coster and Eidmann, 1934). In Java, teak of Godavari (India) provinance resists oxygen deficiency in the soil better than that from Burma, Java or Thailand. Poor stem form and slow growth and perhaps other characterictics, however, make Godavari teak unsuitable for regeneration.

Racial differences in teak have been studied by Coster and Eidmann (1934), Coster and Hardjowasono (1935), Sen Gupta (1939) and Beard (1943). Beard compared races from Tenasserim, Burma, Shencottah and Travancore, and found the Burma race superior for planting in Trinidad.

Morphological characteristics of two Mysore seed origins distingushed in plantations are below:

Character	Kakankote Origin	Shimoga Origin
1. Bole and crown	Trees relatively short, branchy, with branches arching upwards like an inverted sabre. Crowns broader than high, with a tendency to become stagheaded	Trees with relatively tall and well formed boles, few branches, with full roundedcrowns, higher than broad.
2. Leaf length	Varying, generally 14 to 19 inches.	Varying, generally 12 to 17inches.
3. Leaf shape	Oblanceolate to obovate, leafbase cuneate, rounded or obtuse.	Oblanceolate to obovate, leafbase truncate, rounded or acute.
4. Color of leaf veins	Markedly whitish, not hairy.	Brownish, hairy.
5. Lower surface of leaf	Glistens in the sun, feels smooth, whitish.	Hairy, dull, feel rough, dull green, with brownish hairs.
6. Upper surface of leaf	Whitish veins, prominent, feel not scabrid, light-green	Brownish veins, not prominent, feel scabrid, dark-green.
7. Leaf texture	Leathery.	Papery.
8. Petiole	Distinctly petiolate, petiole about half inch long.	Not distinctly petiolate, or with a very short petiole (1/3 inch or less).
9. Leaf tip	Bluntly acute to acute.	Acute.
10. Leaf margin	Generally wavy.	More or less dentate.

A variety of teak called "teli" found in North Kanara (Mysore) has leaves smoother, more shiny and less heavy but darker in color than the standard variety. The boles of "teli" trees are more cylindrical, and the bark smoother and duller colored. The Hudsa plantation of 1923 has teak of this variety. "Teli" trees are believed to grow faster, come to leaf earlier in the season and to have stronger timber. All these characters are believed to be heritable.

Foulks (1895) reported two varieties of teak in South Kanara (Mysore) known by the local names "Kallu-theku" and "theku". The former is confined to the interior, rocky or garelly laterite regions, its trees being stunted, crooked and timber harder and heavier. The latter is found on deeper, richer gneissic soils.

Branching pattern

Laurie (1936) has recognized four different types of branching in teak and discussed the probability of their being hereditary - A. **Big Bud Wolf type** where the tree has a weak leader but has abnormally vigorous lateral growth so that one tree occupies the space of 4 to 5 trees; B. **Horizontal Branching** type where persistent horizontal branches, in fairly widely spaced false whorls, are characteristic. C. **Vertical Parallel Branching** type characterized by a weak leader and strong upward bending branches, mostly lying in a single lateral plane. D. **Candelabra** type caused by a weak leader which is replaced by a whorl of leading shoots (usually 2 to 4) which grow first outwards, then upwards. He has quoted, as examples, the Malalaikatti plantations of 1912 to 1923. Laurie thinks that the types of branching A, B and C are of Kakankote (Mysore) seed origin and, that the growing of seed of this dry origin in the more luxuriant environment of Coorg has exaggerated the hereditary characters. He is possibly right in his assumption that the branching pattern is due to the seed having originated from a drier locality, but may be wrong in the origins he assigns to the different branching types. Branching type B is typical of south Burma origin, types C and D are typical of the Mysore branching type, while type A is not typical of any locality but stray cases of this type are found all over the dry areas of India.[32]

Branching habit is controlled both by environmental factors and the genotype. In Java, teak of Thailand and Indo-China provenances tend to produce the straightest trunks, while strains from Malabar are usually short and branch early (Coster and Eidmann, 1934, Coster and Hardjowasono 1935). Laurie and Griffith (1941) suspect a genetic basis for the development of epicormic branches.

No significant cytological studies on teak have so far been made. Laurie (1936) reported that misshapen trees tend to be more prolific and that random seed collection therefore favors inferior genotypes.

Trees of Kakankote (Mysore) origin differ in branching habit from those of Nilambur origin. Branches of the former are stouter, and curve upwards and inwards, while those of Nilambur teak join the stem at a wider angle and bend outward and downward. This characteristic difference persists in trees from Mysore and Nilambur seed even if they are planted outside their range of natural distribution. Branching habits of trees in the Coorg plantations which have been raised from imported teak seed faithfully reflect their seed origins.

[32] Indian Forester, Oct. 1938, p. 596.

Resistance to adverse conditions is a quality which has also been found to vary between different races and strains. For example, teak of Dehra Dun, (originally North Burma) origin is more resistant to frost than that originating in the Indian Peninsula. Thailand teak withstands the longer and more intensive dry season of East Java better than the local race (Becking, 1950).

Growth

In Java, growth of trees from local seed sources has been compared with growth of trees from other sources. Teak of Malabar (Kerala) origin grew fastest, followed by trees of local (Javanese) and Indo-China origins, which were about equal. Next are the Thailand and Burma origins, and last were those of Madhya Pradesh and Godavari (Central India) whose performance was poor (Van Alphen DeVeer et al. 1957).

Coster and Eidmann (1934) and Coster and Hardjowasono (1935) have found that in Java the local race of teak attains better height and girth than races from India, Burma, Thailand, Indo-China, and Celebes.

Generally teak trees of dry seed-origin grow more slowly and attain smaller sizes than those from localities of moderate or high rainfall. Teak trees of local origin generally thrive better than those of imported origins with similar climate, but there are many exceptions. Teak from a wetter locality, grown in a drier locality may grow faster than the local race. For example, at Kakankote (Mysore) teak of Nilambur origin (150 in. rainfall) is superior to teak of the local origin in germinative capacity and height growth (Kadambi, 1945).

In experimental plots in Mysore, during the first ten years teak of Nilambur origin was superior to all others in height growth and survival percentage. Between the two Mysore origins, that from a moist locality, Shimoga proved better than that from a dry source, Kakankote.

Trees in the All India Teak Seed Origin plantations in Uttar Pradesh, had average dimensions as follows:

Seed Source	Haldwani Division Age 20		Gorahhpur Division Age 22	
	Height, feet	Diameter, inches	Height, feet	Diameter, inches
North Burma	76	10.9	72	9.3
South Burma	77	11.3	71	9.7
Madras (moist)	73	10.4	70	9.4
North Bombay (dry)	66	8.7	61	8.6
South Bombay (moist)	77	10.7	65	9.3
Madhya Pradesh			70	8.9

According to Laurie and Griffith (1941), anatomical characters of the wood are probably determined by genetic factors, and leaf texture is probably correlated with resistance to insect attack and very likely determined by the genotype.

Difference in age or size or condition of teak mother trees does not cause any difference in the height growth of the progeny during the first seven or eight years.[33]

The rate of early height growth of different seed origins may vary, as shown by the following figures from All India Teak Seed Origin Experimental Plots, Tunakadayu range, South Coimbatore Division, Tamil Nadu:

Date	Age (years)	Height in feet S. Burma	Mt Stuart (Madras)	Mysore	Nilambur (Kerala)
January 1936	2	4.5	7.5	7.8	6.7
January 1937	3	13.0	17.1	17.1	15.3
January 1938	4	16.3	21.6	19.4	18.6

Comparable variation also occurred in All India Teak Seed Origin Plantations, Nilambur Division, Kerala:

Date	Age (years)	Height, in feet Nilambur	Anamalais	Travancore	S. Bombay	S. Burma	N. Bu
March 1935	1	4.3	5.3	4.3	5.7	4.2	3
January 1936	2	13.9	14.4	14.6	15.7	15.2	13
January 1937	3	19.4	19.5	19.8	21.3	20.9	17

Fluting and Twist

These defects are more common in certain localities, and are probably inherited. Griffith noted that teak logs from Bori forest, Madhya Pradesh, India, in Taku timber depot had much fluting and considerable twist, and he emphasized the need for great care in the selection of seed.[34]

Disease Resistance

In Java, and Malabar (Kerala) teak seems to be sensitive to attack by *Corticium salmonicolor*, a fungus disease of citrus, rubber and other tropical crops (Becking, 1950).

[33] Silvicult. Res. Rep., Madras, 1943-44.
[34] A. L. Griffith, Tour Notes, Jan. 1943.

Genetic Improvement

Treatment of teak with plant hormores can be useful in clonal reproduction. In Madras, stumps (root and shoot cuttings) treated with the hormore seradix A. started growing 2 to.3 weeks earlier, and had a height increase of 23 percent over untreated stumps. The hormone made no appreciable difference in survival percentage.[35] Experiments at the Forest Research Institute, Dehra Dun indicated that the rooting eprcentage and growth vigor are more in treated than in untreated branch cuttings.[36]

Ferguson (1938), based on his experience in *Cinchona* culture (in which crops consist entirely of graftings from one individual only) has put forward the theory that the factors controlling stem form and branching of a tree, within certain limits, cannot be influenced by external factors such as site and climate.

According to Ferguson the only method of improving the quality is by seed selection. He advocates multiplication of ideal mother trees vegetatively by budding and grafting. With the first trial, 80 percent of teak budding succeeded in Java. He expects many defects, notably fluting, knots, crooked bole or twisted fibre to be improved by seed selection. He also thinks it may be possible to raise a race of teak resistant to the termite *Calotermes tectonea* Dammerman, a pest of teak in Java.

Sprouting Ability

Teak has remarkable ability to regenerate by coppice and pollarding; it retains this ability over much of its life (Fig. 3). During successive years, the new coppice shoot may be longer than the last. However, in Nilambur (Kerala) efforts to improve a backward, 8-year old crop by cutting back and thinning the resulting coppice shoots to one shoot per stool were unsuccessful. The coppice grew rapidly only up to the height of the original shoots, after which growth was very slow.[37] Troup says that of twelve different species coppiced and pollarded experimentally in 1909 Chanda Maharashtra teak had the most rapid growth of both coppice and pollard shoots.

Coppice shoots originate either: (1) from callus growth developed inside the bark and situated between the bark and the cambium, or (2) from the side of the stool below the cut surface. The former are of adventitious origin and the latter probably originate from dormant buds. High coppicing appears to prevent the formation of callus shoots.

Experiments in Jubbalpore district, Madhya Pradesh, to determine the most suitable season for coppice fellings, indicated that March and September are probably the best for this locality.

[35] Silvicult. Res. Rep., Madras, 1939-40, p. 37.
[36] Res. Rep. Forest Research Institute, Dehra Dun, 1950.
[37] Madras Research Notes 48, 49, 1936.

Figure 3. *Teak has remarkable sprouting ability. A teak stump 12½ feet in girth with its sprout about 3½ feet in girth. Allapalli, Maharashtra.*

The worst period extended from the time vegetative activity commences to a short time after full development of foliage. [38] It was also found best to coppice teak just before commencement of its vegetative activity when sap starts rising. In dry, hot localities, coppicing at the height of the drought season is not advantageous as

[38] Forest Pamphlet No. 16, Bot. Series, No. 1, 1910, p. 29.

this may result in the death of the cambium on the coppiced stools. In West Chanda division, Maharashtra, stools coppiced in successive months, from April to September, showed that all stumps coppiced in April and May produced shoots but for those coppiced later, percent success was 92 for June, 91 for July, 40 for August and 71 for September. In the case of old, hollow stumps cut flush with the ground, coppice shoots may develop independent plants or become independent owing to decay of the old stump. Experiments in Madras showed that height of coppicing (up to 12") and trimming of stools did not affect mortality of stools or the number of shoots per stool.[39]

Teak does not produce typical root suckers. Usually, teak sucker shoots are not situated so far from the parent stem that their point of attachment to the parent could not have been reached by a buttress or a lateral extension of the stem.[40] Fernfandez (1876), who examined over 5,000 teak stools did not find a single one that had not sprung up in contact with old stools.

Seed Characteristics

Weight of seed varies widely with locality 650 per pound being reported in West Bengal, 1600 in dry localities of Utter Pradesh, 960 to 1550 in Madhya Pradesh, 1200 to 1600 respectively in wet and dry sections of Maharashtra, 650 in Tamil Nadu, 730 in Kerala and 860 to 880 respectively in moist and dry localities in Mysore. Weight and volume of Java seed are reported as follows: [41]

Origin	Weight of 1000 seeds (grams)	Volume of 100 seeds (cubic centimeters)	Number of Seeds	
			per kilogram	per liter
Noord Kedoenggalon	615	2080	1650	480
--do--	562	1970	1800	510
--do--	631	2210	1600	450
--do--	589	1920	1700	520
Tiaback	692	2680	1450	373
Proefperk	749	5230	1350	190
--do--	761	5230	1300	191
--do--	767	5560	1300	180

Germinative capacity and plant percent also vary within wide limits for seeds from different parts of India and Burma but, in general, the expectancy is low for selected seed. The following table gives details:

39 Silvicult. Res. Rep., Madras, 1949-50.
40 Indian Forester, 1914, p. 192.
41 Korte Madedelinger van het Boschbouproef Station, 1931, Tectona, Vol. XXIV, 4.

NATURAL REPRODUCTION

Because teak is easily planted and tenacious after establishment and because it was the first forest tree to be planted in India on a large scale, teak growers have paid meager attention to its natural reproduction. On the basis of their natural regeneration, deciduous teak forests of India can be placed under two categories:

1. Moist, with sparse stocking and inadequate natural regeneration of teak; well formed clumps of *Bambusa arundinacea* are present in the nearly complete canopy. Most forests of Kerala, a few of North Mysore and many forests of Burma belong here.
2. Relatively dry, with abundant teak and its natural reproduction associated with *Anogeissus latifolia*; clumps of *Dendrocalamus strictus* are found in the moderately open canopy: the forests of Madhya Pradesh, Maharashtra and the drier forests of Mysore and Tamil Nadu belong here.

Where teak has been planted outside its range of natural distribution in India, and wherever it has been introduced in Africa and the Western Hemisphere, it regenerates naturally, but generally not where it is endemic.

Factors Affecting Reproduction

Factors which influence natural reproduction of teak include: (1) climate, (2) soil, (3) capacity of seed for ready germination, (4) conditions conducive to establishment of the seedling, and (5) method of management.

Where teak is endemic, generally, there is a sharp alternation of a dry season with a wet one; this is beneficial to its regeneration because the fruit which is shed at the beginning of the dry season weathers in that season, soaks in the premonsoon showers of April-May, dries out in the monsoon break that follows and finally soaks again in the monsoon. If the break between the premonsoon and monsoon should be too long, the seed whose germination would start in the premonsoon rain would die (Kadambi, 1959). The hard seed coat beneath the teak seed's spongy layer protects it from premature germination during premonsoon rains. Failing this, the drought sensitive radicle would perish by any holding off of rains. If the first, good premonsoon showers are followed by a long dry spell, hardly any germinating seedlings can survive.

The variety of rock formations and resultant soils on which teak thrives indicates that it is not the chemical composition but rather the physical structure of the soil, more especially its porosity, that is responsible for success of its natural reproduction. Granite, gneiss and trap produce moderately favorable soils; basalt and sandstone develop soils that are adequately porous, but on the latter humus disintegrates too rapidly. Teak regeneration does not thrive on laterite because humus is rapidly leached out.

Teak usually seeds abundantly, but the floor of a natural teak forest of the moist type often has a dense undergrowth which obstructs the teak radicle from reaching the soil. Excessive opening of the forest canopy to secure regeneration may stimulate the growth of grass and other weeds which smother many of the young seedlings (Kadambi, 1957, 1959).

Only on soft, friable soil does a teak seedling develop the strong taproot needed to tap the deeper moisture supplies necessary for survival during its first summer drought. Shade and drip from seedtrees also hamper seedling development; few teak seedlings persist under seed trees after the end of the rainy season.

In cool shady places teak seed may lie dormant for years. Coster (1933) says that a temperature of 33°C is required for germination which, in teak areas, is provided by the sun and by ground fires. Hole[49] found by sowing seed in two identical plots, one shaded the other not, 17 percent germination in the latter and 1 percent in the former. On admission of light into the shaded plot after two years the dormant seeds germinated immediately.

In natural forests, the annual ground fires scorch the seeds and facilitate germination by removing a portion of the seed coat. An accidental fire in Bengal resulted in a good crop of seedlings where there were none before.[50] In a burned experimental plot in Betul division of Madhya Pradesh there were 26 percent new seedlings against none in the unburnt plot.[51] However, fire is beneficial only in heavy rainfall areas, but is unfavorable in low rainfall areas as it destroys humus and makes the ground surface hard.

Seedling Establishment

Light is one of the most important factors affecting establishment. In moist localities light is indispensable from early infancy but not in dry hot localities like Madhya Pradesh and Andhra Pradesh where protection from the severe afternoon sun is advantageous. However, overhead trees bring in another adverse factor, drip.

In heavy rainfall areas mortality of seedlings is high owing to temporary waterlogging and hemming-in by damp weed growth during rains. In dry areas drought is the principal enemy to seedling establishment. Root competition from weeds and grass increases the difficulty of seedling establishment in such areas. Forking and scrape weeding, which combine soil working with removal of weeds,

[49] Indian Forester, 1916, p. 51.
[50] Indian Forester, 1917, p. 35.
[51] Indian Forester, 1932, p. 12.

are more advantageous than weed cutting. Excessive grazing when seedlings are very young prevents establishment of teak, but limited grazing helps by keeping down heavy grass.

In the moister type of teak forests of India and Burma, fire protection adversely affects regeneration establishment by encouraging weed growth and allowing the forest to progress to the evergreen type, which shades out teak. Troup showed in Tharawady, Burma, that younger age classes of teak were ten times more numerous in an area exposed to frequent fire than in a protected one.[52] Teak being more fire-hardy than most of its associate species, in pertinent situations fire helps establishment and development of seedlings (Troup, 1921 Pp. 762-64). The almost pure teak stands of Java probably result from elimination by fire of the associates of teak.

On the contrary, fire is harmful to teak in dry deciduous forests as it kills teak regeneration. Even, so light burning and controlled grazing are useful for inducing regeneration by keeping down weeds and grass. Uncontrolled burning deteriorates the soil by destroying soil improving flora and bacteria and increases danger of soil erosion.

In frosty localities seedlings are repeatedly frosted back, but the rootstock survives and grows stronger until it can develop a shoot which rises above frost level.

Natural reproduction is induced in the drier forest types, as in Central India, by protecting the crop from fire for 2-3 years, and felling or girdling all excepting a few seed trees; a young, more or less even-aged teak crop emerges (Fig. 4). Regeneration is induced in the moister forest types, as in Burma, by burning the forests for 2-3 years in dry season, and keeping the area well weeded until teak plants are well above weed level.

Though artificial regeneration is almost universal, instances of natural reproduction are not wanting. Except where tall grass or dense bamboo is present, natural reproduction is common in Hoshangabad division, Central India. The large patches of teak found in Mohnyin forest of Upper Burma are largely due to abandoned cultivation. The factors which encourage such regeneration are: (1) the lasting viability of teak seed, (2) slash burning and soil working during cultivation, and (3) annual forest fires which keep out competitors of teak (Troup, 1921 p. 728). Full stocking by natural reproduction has been obtained in Katha division of Burma, a moist zone, by girdling the overwood and growing an agricultural crop (taungya) under the girdled trees.[53]

52 Indian Forester, 1905, p. 138.

53 Burma Forest Bull. (Silvicultural Series) 1, 1921.

Figure 4. *Natural reproduction of teak, Madhya Pradesh, central India, resulting from felling and girdling the old crop and cleaning bamboo. Anthill in the foreground.*

Role of Bamboo in Natural Reproduction of Teak

Various kinds of bamboo found in teak forests often play a vital role in the natural reproduction of teak. Little teak regeneration survives under vigorous bamboo stands. Gregarious flowering, a phenomenon which occurs periodically in most bamboo species and which is followed by death of the bamboo plants, affords an opportunity for establishment of teak from dormant seed. Cutting and burning the bamboo may provide similar conditions favorable for teak establishment. In either case cutting or burning of young competing bamboo is necessary to insure survival of a satisfactory stand of teak.

In Madhya Pradesh regeneration of *Dendrocalamus strictus* bamboo supresses and destroys a portion of teak regeneration, but the rest persists and stagnates under the bamboo until released at the next wholesale flowering. In Hoshangabad division, Central India, natural regeneration is being established by cutting back and burning the bamboo which interferes with the natural reproduction of teak and supplementing such regeneration, where necessary, by planting teak stumps under the old canopy. In Hoshangabad and West Chanda division of Central India, natural regeneration of teak has been induced by cutting the bamboo twice, once a few years before the main timber fellings and once again during such felling.

In the drier teak forests of Burma, natural reproduction can be established by taungya. In North Pegu Division the bulk of teak reproduction comes in after a bamboo flowering, and persists under the bamboo (*Bambusa polymorpha*) until the next flowering. Having thus developed a substantial root stock, it forges ahead in the fresh canopy openings. Successful regeneration of teak was obtained with the flowering of *Cephalostachyum pergracile* after a light clearing of overhead cover and creating small gaps around teak seed bearers. If overwood is heavily opened, early and repeated weeding will be necessary. It is advantageous to protect the area from fire as soon as there is enough regeneration.[54]

Cleanings and burning around seed bearers and in dense bamboo areas result in increased natural reproduction.[55] In case of bamboo the hottest possible fire has to be obtained. Annual fires and unrestricted fellings of non-teak kinds by villagers are probably responsible for abundance of natural reproduction in village lands and old taungyas of North Zamayi reserve, Pegu Division. In North Toungoo division, natural reproduction of teak was obtained by burning bamboos and species other than teak and *Xylia dolarbiformis.* In Myitkyina Division, good regeneration was obtained by broadcasting teak seed before the regeneration area was felled and burnt.

[54] Indian Forester, 1918, p. 666.

[55] J. W. A. Grieve, 1919, Inspection note of Myitkyina Division, Burma.

The prevalence of artificial methods for establishing and regenerating teak forests reflects a widespread opinion that these measures are silviculturally and financially justifiable. The high value and rapid growth of teak, and the ease of establishing it by planting, have stimulated plantings in favorable localities around the world (Fig. 5).

Figure 5. *Teak seed-origin plantation, South Burma origin, Ramgrah, Uttar Pradesh. Notice the whorled branching, and the knotty bole caused by epicormic branches. Crop height, 71 feet, gbh 2½ feet.*

As with other monocultures, many objections have been raised to the growing of teak in even-aged plantations. These have included allegations that plantation teak grows slowly after about 20 years, deteriorates site, causes soil erosion; that it develops excessively fluted boles and epicormic shoots, is subject to excessive attack by bee-hole borers, defoliating insects, and mistletoes; that its timber is of inferior quality, and that pure teak is difficult to regenerate.

There is no sound evidence for excessive fluting in plantations, and tests of plantation grown teak have shown it fully equal in strength qualities to natural teak of comparable growth rate. Prevalence of knots and defects due to epicormic shoots is at least partially hereditary, and considerably dependent on growing conditions. Selection of seed and appropriate management during the growth of the plantations should produce timber on good sites equal in all respects to natural grown teak.

Attack by bee-hole borers appears to be somewhat more severe in plantations although differences are small where attacks are heavy. Defoliaters (*Hybalea puera and Hapalia machaeralis*) are reported to be no more serious on plantations than on natural forest in Tamil Nadu, Maharashtra, Orissa and Mysore [56,57] (Kadambi, 1945, p. 62). Generally, however, defoliator attacks are more serious in pure teak plantations, especially where there is no undergrowth. Attack by mistletoes (*Loranthus* spp.) is generally less severe in natural forests than in plantations.

While growth of some Burma plantations has reportedly slowed seriously by age 20 or earlier,[58,59] continued rapid growth has been reported from West Bengal, Tamil Nadu, and Kerala.[60] Similarly, reports of lowered site quality are refuted by growth of second rotation crops at Nilambur (Griffith and Guptha, 1947) and by reports that no soil deterioration (except erosion) has occurred in Burma,[58] Kerala and Mysore. It is reported that some site deterioration may have occurred in the drier parts of central India.[61] Soil erosion in teak plantations, both in Burma and India has been confined to areas where undergrowth has been cleared and where burning has been excessive. Management which maintains a protective understory of favorable species can probably avoid both soil erosion and site deterioration under pure stands of planted teak. Good management, too, can overcome the difficulty of regenerating teak plantations, which stemmed largely from lack of sufficient slash to provide the hot fire needed to prepare a good seedbed. It is now possible to insure good growth with a less severe burn by early "stump" planting and timely release.[62] On suitable sites, as at Nilambur, the taungya method of planting teak with an agricultural crop has been most successful and economical.

[56] D. J. Atkinson, Indian Forester, 1926, p. 141.

[57] C. F. C. Beeson, Indian Forester, 1928, p. 204.

[58] H. R. Blanford, Indian Forester, 1922, p. 429.

[59] Proc. 3rd Silvicult. Conf., Dehra Dun, 1929, Pp. 79-80.

[60] Proc. 4th Silvicult. Conf., Dehra Dun, 1934, Pp. 125-136.

[61] Silvicult. Res. Rep., Central Provinces, 1936-37. p.5.

[62] A. L. Griffith. Indian Forest Rec., 1939.

Extent of Teak Planting

Information on plantings of teak is incomplete for many parts of the world where the species has been planted; for other areas, good statistics are available.

The area of teak plantations in India, including mixed plantations with teak as the main species, is close to 700,000 acres as shown in the tabulation below.

	Area of Teak Plantations	Annual Planting Program
	acre	
Uttar Pradesh	16,500	no information
West Bengal	14,820	1,729
Assam	14,300	1,100
Bihar	1,850	no information
Orissa	57,645	18,352
Madhya Pradesh	113,000	no information
Maharashtra (includes Gujarat)	35,872	2,598
Andra Pradesh	67,678	4,000
Mysore	203,800	6,500
Tamil Nadu	11,792	618
Kerala, without Nilambur	39,087	no information
	12,147	495
Total	688,491	35,392 (in 8 states)

In Uttar Pradesh, teak planting was started between 1868-72, and planted teak regenerates naturally. Provided it escapes years of severe frost, teak grows fairly well as far north as Dehra Dun. Teak is also planted in gaps caused by failure of sal (*Shorea robusta*) or in taungyas. In West Bengal the oldest plantations, in Darjeeling **tarai**, were formed in the sixties of the last century. The Kulsi teak plantations of Kamrup district, Assam were commenced in 1872. Underplanting of teak in dense evergreen cum *Bambusa arundinacea* forest, was started in 1884-5 and underplanting in lines in sal forest ofAngul division, Orrissa, in 1886. In Andhra Pradesh teak was first planted in Sipra Valley of Melghat forest division in 1868, and up to 1,000 acres were completed by 1879. The earliest plantations of North Kanara district (old Bombay state) were formed in the Kalinaddi River Valley at Kadra in 1866, Suligere, 1867, and Mardi, 1869-70.

Except for the pioneer efforts at Nilambur in the early 1840's, major teak plantings in India began during the decades from 1865 to 1885. In Uttar Pradesh, West Bengal, Andhra Pradesh and northern Kanara, earliest plantations were established before 1870. Plantings were underway in Assam in 1872, and by 1885 had been extended to underplantings in sal, evergreen and bamboo forests.

The plantations at Nilambur, Kerala, now (1970) comprising some 12,000 acres with annual gross and net production of some $2.8 and $1.3 million (Rupees 16.3 and 10.1 million), have led in silvicultural research and methodology for 125 years. Alluvial soils, 100 inches of rainfall, equitable temperatures of 80 to 90°F, elevations about 100 ft. above sea level, and accessibility by roads and a floatable stream, combine for profitable timber production. Nevertheless, more than three quarters of a century had elapsed before the major management problems had been fully solved.

Chatu Menon, "father of Indian teak planting," [63] was in charge of the plantations from their inception in 1842 until 1862. Working closely with Conolly, civil administrator of Malabar District, Menon solved the multiple early problems of site preparation, seed germination, seedling production and survival. Before his retirement, the plantations contained well over a million vigorous trees.

The decades prior to 1883 saw the development of procedures for thinnings, cleanings, weedings, parasite cleanings, and fire protection, as well as experimental introductions of rosewood, mahogany, rubber and other species, both in pure stands and in mixture with teak. Limited financing prevented optimum cleanings and weedings in early years, but by 1878 regularly scheduled thinnings were being conducted, evidently at a net profit. While successive forest administrators recognized the advantages of thinnings, their programs sometimes varied rather widely. By 1893 only mahognany, (*Swietenia macrophylla*) had proved useful as an associate for teak.

During these decades serious questions were also raised about the quality of plantation teak. A conservator in 1872 reported signs of premature decay. Although four years later these indications were no longer noticeable, he questioned the quality of timber from the plantations. Tests in 1880-81, however, showed it better than some natural teak in specific gravity, and intermediate in strength between natural teaks from various sources. Obviously, growing teak in plantations had not impaired its quality.

As late as the first decade of the twentieth century there were plantation failures at Nilambur and elsewhere resulting from poor site selection, and for a time (1911-1916) teak planting was suspended. While detailed soil mapping to avoid laterite and under-aerated subsoils was proposed as early as 1898, soil factors were not fully recognized in teak planting, even at Nilambur until the early 1920's.[64]

Mysore

In less than a decade after Conolly started his famous plantations at Nilambur, the first teak plantations were founded in Mysore state on the banks of river Tunga at Sakrebyle, a village about 8 miles

63 Indian Forester, 1947, Pp. 698-500.

64 Forest officers who played important roles in the development and administration of the Nilambur plantations include: Conservators Morgan, Beddome, Cleghorn and Campbell Walker, and working plan officers Lushington and Bourne.

from Shimoga. The most successful remnant of this series of plantations covering about 300 acres and called "Kanive" plantations, had trees averaging 5 ft. 7½ in., in girth (20.7 in. diameter) and 98 fet. 2 in. in height at the age of 91 years in 1945.

In 1862-63, a second series of plantations were started along the Bhadra river by Oswald, the most successful of which had reached by 1950, an average girth of 5 ft. 6 in. (21 in. diameter) and height of 97 ft.

Between 1872 and 1875 the first teak plantations were started at yet another famous teak locality called Kankote, also famous for the best part of two centuries as the scene of "Khedda" elephant capturing operations. These plantations should be looked upon as the most successful of the very early plantations because in no portion of the area did the planted teak fail, and by 1956 when 84 years old, the trees here averaged 5 ft. 4 in. in girth (20.4 in. diameter) and 82 ft. in height.

Teak has disappeared altogether from portions of the area planted up in those early days having been replaced mainly by *Bambusa arundinacea* and *Terminalia tomentosa*, but what has remained contains some of the best bits of artificially regenerated teak forest we still have in parts of Mysore. With the turn of the century the need for and the value of teak plantations was fully appreciated. The silvicultural demands of teak were known in more detail and influence of soil drainage on teak growth was realized. The idea that proximity to running water is an essential factor for the success of a teak plantation was gradually abandoned, and plantation sites were selected wherever drainage and soil were suitable. The first World War and the subsequent timber boom gave a further impetus to teak planting. The greater part of India's teak plantation thus dates from post World War I years. In the early thirties, over two thousand acres of teak plantation were formed annually, and plantation technique was greatly improved by perfecting the stump planting technique practiced since 1926.

The outstanding progress of the decades between 1930 and 1960 is in reduction in the cost of exploitation, standardization of methods and procedures of artificial regeneration, working out thinning regimes, preparation of yield and volume tables, recognition of teak races and some understanding of the genetic properties of teak.

Burma

Teak plantations were started in Burma in the fifties of the last century, several among them being associated with the name of Brandis, the first Inspector General of Forests, India-Burma, and called "Father of Indian Forestry". Among these is the Myodwin plantation of Tharawady district, formed by clearing and burning the existing jungle and digging up the soil. Taungya plantations were started in Tharawady in 1869 on a small scale at first; since 1873 they have been extended almost continuously. This method is admirably adopted to the habits of the jungle population in Burma. Conversion of natural forests also proceeded on a modest scale.

Other Countries

Planting of teak commenced in countries outside India and Burma more or less in the following years: Ceylon (Divulana), 1872-75; West Malaysia, 1954; Indonesia (Java), early 20th Century; Thailand, 1942; Africa: Zambia, 1958-60; Tanzania, 1909-10; Uganda, 1930; Ivory Coast, 1929; Dahomey, Ghana, Togoland, 1902-10; Nigeria, 1911; Western Hemisphere, Trinidad and Tobago, 1913; West Indies, 1951; Honduras, 1927, and Panama, 1920's.

Table 4 summarizes the available information on teak planting in various countries.

Seed Collection and Storage

Teak seed is generally collected by cleaning the ground under the mother trees during the ripening season and sweeping up the seed. Daily collections are recommended to avoid collecting insect-attacked seed, but collection every few days would be enough in places where there is no insect attack. Dry fruits often stick to the inflorenscence and have to be beaten off with a stick.

Seed collection time is generally January to March in Assam and most parts of central and south India, including Mysore and Bengal and November to January in Burma and Madhya Pradesh (Sen Gupta, 1939; Homfray, 1935). The time is December-February in Uttar Pradesh,[65] March in Bihar and Orissa (Osmaston, 1935). January-February in dry locations in Maharashta, February-March in Malabar (Kerala) and Tamil Nadu.

[65] Uttar Pradesh Forest Dep. Bull. 14, 1940.

Table 4. Teak Plantations in Southeast Asia, Africa and the Americas.

Country	Area of Teak Plantation	Annual Planting program	Planting Methods	Remarks
	----------------acres----------------			
Southeast Asia				
Cambodia (Phnom-Penh)[1]	6,669	370-496	Taúngya largely practiced on good soil with peanut, sesamum and cotton. Direct sowing of seed: Failures replaced with stump plants.	Height of good plantations 74 ft. with dbh over 19 in.; no natural teak in Cambodia.
West Malaysia[2]	400	40-50	Stump planting, Taungya wiht hill rice, tobacco, chili, corn and vegetables.	Oldest plantations 15 years, 90 ft. tall, on deep alluvium.
Ceylon[3]	66,038	15,000	Taungya mostly, stump planting; sprinkler irrigated nurseries.	Oldest plantations date back to 1872-1875.
Java[4]	1,422,226	37,050	Taungya 2 to 3 years, sowing 5 seeds per hole.	Oldest plantation 120 years old; 36 meters high.
Thailand[5]	30,000	4,000	Mostly taungya; stump planting.	Intensive efforts at teak planting not made until 1942.
Africa				
Zambia[6]	4.4	--	Stumps & entire plants.	Grown on a research scale from 1958-60; 24 1/10 acre research plots and one plot of 2 acres were planted. Clean weeded for 5 years; NPK 3 ozs., & 1½ ozs. fertilizer borate applied to each plant.

Table 4, continued

Tanzania[7]	2,500	700	Stump planting after clearfelling; without taungya.	Oldest plantation 60 years; crop height 96 ft. & crop dbh 14.6 in; M.A.I. in younger plantations 200-300 cu. ft. per acre/per year.
Uganda[8]	less than 50 acres	--	Stump planting, in arboreta.	Planted since about 1929 in 1/10 acre plots, none of which has shown promise.
Ivory Coast[9]	12,045	590		
Dahomey[10]	29,640	1,800		
Ghana	500	--	Stump planting, generally with taungya.	First planted about 1905.
Nigeria[11]	20,000	5,000	Stump planting with taungya usually, at least in the southern states.	First planted about 1911. 1917 planttıon at Olokemeji 90-100 ft. high & 5-8 ft. in girth.
Togoland[12]	14,820	267-312	Stump planting with Taungya. (50% area)	Less than 25% of the area planted is valuable. Planting program to be increased to 741 to 1233 acres. Plantations raised in savannah areas; age classes vary from 0-10 years to 40-60 years.
Kenya[13]		1½	Stumps planted without taungya near the coast, & with taungya at altitude of 5,500 ft. in an experimental area.	Most trials are made at altitudes below 1,000 ft. near sea coast. The oldest trials are 15 years old.
The Americas				
West Indies[14] (St. Vincent)	25	3	Stump plants; taungya or other	Temporary nurseries; beds 4½ ft. wide; oldest trees are 18 yrs. old 70-80 ft. high.

Table 4, continued

Trinidad Tobago[15]	18,000	600	Stump plants ½ in. thick. 10 months old in nursery. Taungya with hill rice, pigeon peas, **Dioscorea** spp., zea-mays, etc. Area cleared by the taungya agent who also tends teak in the southern portion of Trinidad where most of the teak is grown. In Northern Trinidad the taungya agent is paid 15 dollars per acre for his work.	Temporary nurseries: beds 4 ft. wide. Height class I 80-90 ft. at age 50 Height Class II 70-80 ft. at age 50. Height Class III. 60-70 ft. at age 50 Envisaged rota tion 60, 70 and 80 years respectively. First introduced from Malabar coast of India in 1913 and 1915.
Panama[16]	1,606	50	Stump plants; taungya not practiced; spacing 2½x2½m.	Oldest plantations date back to the 1920's but very poor.
Honduras[17]	2,370		Stump plants; taungya practiced.	Teak first planted in 1927. Regular teak planting program initiated in 1942
Puerto Rico[18]	1,300	30	Stump plants; without taungya.	Oldest plantations 30 years old, with commercial bole height of 30 ft.

[1]Min. Agr., Royal Cambodian Government Commun. 11098/Br., Dec. 16, 1969.
[2]Dir. Forest., West Malaysia, Commun. J. H. 14/54 (15), Dec. 5, 1969.
[3]Conserv. Forest., Box. 509, Colombo, Ceylon, Dec. 14, 1969.
[4]Dir. Dep. Agr. Bogor, Indonesia, Ref. 033/111/1, Jan. 8, 1970.
[5]Kaufman, 1968; J. Forest. 66:396-399.
[6]Chief Forest Res. Officer Commun. 1237/M6/32, Dec. 19, 1969.
[7]Dir. Nat. Res., Commun. FD/35/11/6, Dec. 8, 1969.
[8]Chief Conserv. Fores., P. O. Box 31, Etebbe, Uganda, Commun. N0. 293, Nov. 27, 1969.
[9]De La Mensbruge, 1957.
[10]Quint, 1957.
[11]Dr. Forest Res., Ref. G.481/2/215, Feb. 6, 1970.
[12]Le Chef du Service des Eaux et Forests du Togo, Lome, letter no. 982 of Dec. 29, 1969.
[13]Silviculturist, Forest Dep. Box 74, Kikuyu, Kenya; Jan. 14, 1970.
[14]Chief Forest Officer, St. Vincent, W. Indies, Commun. A. T. T. 48, Dec. 18, 1969.
[15]Asst. Conserv. Forests, Res., Commun. R. F. 8/7/7, Dec. 3, 1969.
[16]Ingeniero Forstal, Republica de Panama, Letter SF. 243, Pna. 6, Dec. 5, 1969.
[17]Schubert, 1959; Teak plantations in the Republic of Honduras. Harvard Univ., Cambridge, Mass.
[18]Dep. Agr., San Juan, Puerto Rico, Mar. 4, 1970.

For convenience of transport and storage, the bladder-like calyx has to be removed, either by rubbing the fruits between the palms at the time of collection or, better, by vigorously shaking and rubbing the seeds in a partly filled bag and separating the husk of the crumpled calyx by winnowing. Homfray (1935) prescribes drying the seed in the sun for 6 to 7 days before storing.

The seed stores well and can be kept for at least two years in a sealed tin without appreciable loss of viability. It also keeps well in a gunny bag. Germination of seed stored for one year is often as good if not better than that of fresh seed. Sown seeds sometimes remain dormant in nursery beds, and germination takes place in the following or subsequent years [66] (De, 1940). Seed from very dry localities shows more persistent dormancy than that from wet ones (Griffith and Guptha, 1941). Storage tests at Dehra Dun showed generally a reduction of germinative capacity from 20% in the first year to 2% in the 11th year.

Dormancy

Seed from dry and moist climates varies greatly in the ease with which it can be germinated. Nearly all teak seed, however, shows some degree of dormancy, making it difficult to get quick, even and adequate germination. The main cause of delay in the germination of teak seed is the failure of the thick pericarp to soften sufficiently for the embryo cells to open (Fig.6). Sown at the beginning of the rains,

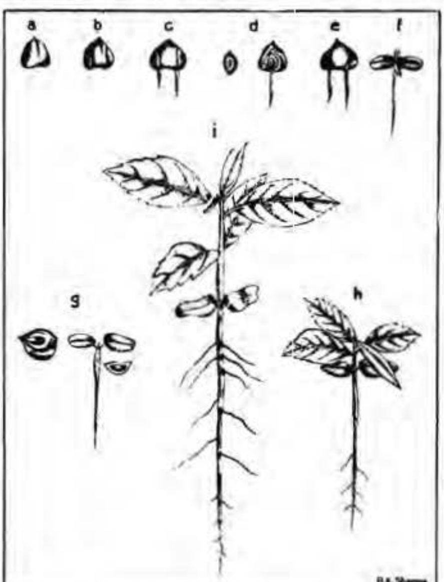

Figure 6. *Stages in the germination of teak seed; observe the emergence of twin radicles* (c,e) *from two embryos within a single teak seed* (fruit) *X*¼.

66 Indian Forest Rec. 7 (11).

teak seeds do not, as a rule, germinate well in most parts of India, and regeneration by direct seeding is usually patchy. Except for sowing in nurseries that can be irrigated, presowing treatments should prepare the seed only up to a point, and the monsoon proper should give the final impetus to germination; in direct seedings, germination much before the rain could be a disaster.

In general, teak seed from dry zones is relatively difficult to germinate, that from moist zones requires little presowing treatment. Most authors recommend alternate wetting and drying to hasten germination (Champion and Griffith, 1948; Troup, 1921). Maximum germination was obtained in the Phillipines by Donoga [67] (1939) by sowing seed in a mixture of clay, loam and ash, or storing the seed for up to 65 days in a shady pit.

Methods of Stocking

Direct sowing of teak seed, and transplanting of intact seedlings, though still in limited use, have largely been supplanted by the effective and efficient "stump planting".

Direct Sowing

Being cheap, simple and adapted to unskilled labor, direct sowing has given fairly satisfactory results, and is practiced generally in Java, and to some extent in Burma (Kermode, 1957). Sowing is done at stakes spaced generally 6 ft. x 6 ft. after soil preparation; 3 to 6 seeds are sown at each stake (about 3½ to 7 lbs. of seed per acre), and covered with ½ to 1 inch of soil. Seed is sown at the end of May or early June. Casualties are sometimes heavy and are replaced by transplants or stumps during the rains. In Java, teak is raised with taungya crops at the beginning of rains in October by sowing 74 liters of seed per hectare, in rows along with an equal quantity of *Leucaena glauca* seed. In December, teak plants are thinned to one plant per meter (3.3 feet) in the rows. (Van Alphen De Veer and others, 1957, P. 219).

Best results with sowing can be obtained only in localities where weeds are scarce and the soil has been thoroughly worked before sowing.

Transplanting Intact Seedlings.

This method has now almost disappeared except for replacing casualties. Plants 3 months old and about 3 in. to 1 ft. high, are planted in cubic pits 12 to 18 inches deep.

[67] Silvicult. Ledger Files, Dehra Dun.

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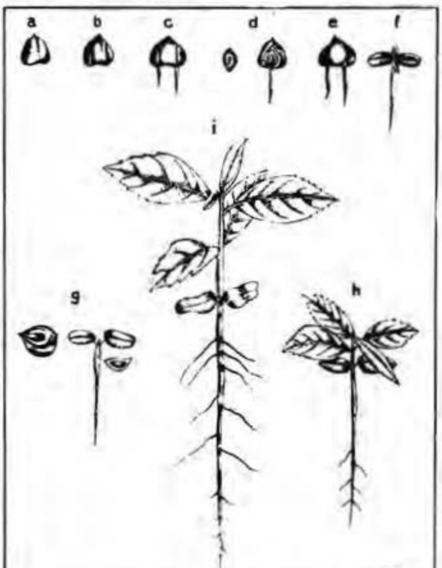

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[67] Silvicult. Ledger Files, Dehra Dun.

What is called dona planting has been practiced in parts of Madhya Pradesh and Orrissa. Nursery seedlings about 2 to 3 weeks old, which have developed their second pair of leaves, are pricked out into donas or leafcups, filled with good garden soil. Leaves used for donas are of *Butea frondosa, Butea superba* or *Bauhinia valhii.* Donas are kept in shade and watered daily, excess water being drained off through small holes at the bottom of the cups. At the break of rains, the dona plants, which are 4 to 8 inches high, are planted out in pits. The method is expensive and has therefore been mostly replaced by stump planting. [67]

Stump Planting.

Planting teak stumps, i.e. root and shoot pruned plants, in stake holes is the commonest and most successful method of stocking. It has greatly simplified teak planting, increased the percentage of survival and improved early height growth. Its use has reduced plantation costs by the equivalent of a full year's weeding costs, and better stocked and grown plantations have generally resulted. Stumps, unlike transplants, can be planted a couple of weeks before the break of rains, and give much quicker height growth than normal monsoon planting. In general, in localities enjoying a summer monsoon in the Northern Hemisphere, the appropriate planting time would be immediately after the first, adequately heavy premonsoon or early monsoon showers when the ground becomes soft enough to make planting holes with a pointed wooden stake. In West Bengal, Assam, Kerala (Malabar coast) and Mysore (Shimoga and Kakankote) stump planting is done 4 to 6 weeks before monsoon, in the east coast of Tamil Nadu and Santal Parganas of Bihar 2 weeks before the monsoon, in North Kanara district of Mysore a week before the monsoon and in Uttar Pradesh, Bihar, Marharashtra, Gujarat, Madhya Pradesh and parts of Kerala (Travancore) in the latter part of May or early in June.

Suitability of stumps for artificial regeneration was investigated[68] and confirmed by Champion and Pant, the best technique for planting stumps was investigated by Griffith and Guptha (1942), who concluded that in the Indian west coast type of climate, the most appropriate root length and diameter for stumps would be 6 to 8 inches and 0.6 to 0.8 inches respectively. Stumps from plants one to two years old in the nursery gave highest survivals.

Nursery Practice

Teak Pre-sowing Treatment.

Among methods advocated in India and Burma for hastening germination of teak seed are:

[67] Silvicult. Res. Rep., Central Provinces, 1936-37, p. 8.

[68] Silvicult. Ledger Files, 1932, Dehra Dun.

(1) Scorching the seed with a light fire of dry leaves or grass,
(2) Immersion in hot water for a few hours,
(3) Immersion in boiling water, i.e., bringing the water to boil, putting seed into it and allowing the whole to cool,
(4) Immersion in cold water for several days,
(5) Alternate soaking and drying,
(6) Burying seed for a year near an anthill,
(7) Soaking in a mixture of cow-dung and water,
(8) Soaking in concentrated sulphuric acid for about twenty minutes, and thorough washing in water before sowing,
(9) Weathering, i.e., exposing the seed to sun and rain by leaving it in the open for a few weeks or months.

All methods of alternate soaking and baking set up stresses to split the seed coat and release the germinating embryo.

M. D. Chaturvedi [69] has described a treatment bed used in Uttar Pradesh to hasten seed germination:

Brushwood is loosely spread on well drained ground; this is covered with loosely packed grass and interspersed with twigs and branches. A one-inch layer of coarse sand is spread on the grass; the seed is spread over the sand and covered with a thick layer of rich forest soil. The bed is soaked with water every evening. The sand gets very hot during the day and this heat is conserved by the layer of grass. The soaking given in the evening promotes rapid cooling. This alternate heat and cold induces germination wtihin 10 to 25 days.

The following additional methods of hastening germination of teak seed have been suggested by S. H. Howard:[70]

(1) Soaking in water for 48 hours before sowing, then sowing in a nursery bed in the sun, covered with straw and soaked daily.
(2) Spreading seed in 4 in. thick layer in the sun on a mat and watering constantly. Germination starts in a few days. This method is used in Ceylon.
(3) Soaking in warm water for 48 hours. This is supposed to induce germination in 24 hours.
(4) Digging a 2 ft. deep pit in the sun in April and spreading alternate layers of earth and teak seed each 1 in. thick; flooding the seed with water every third day for 6 weeks and spreading in the sun for 3 weeks.
(5) Soaking in water for 24 hours, spreading in the sun for 4 days, and continuing this process.

In parts of Africa, seed is soaked in a pit for three to four days, and seeds which show signs of germination are lined out in nursery beds. [71]

[69] Indian Forester, 1942, p. 457.

[70] Forest Pocket Book, 1937.

[71] Farm and Forest, 1941, 2 (2) p. 74.

In the Phillippines, burying the seed in a shaded pit for 20 to 60 days has been found useful. In West Africa, Ghana, Nigeria, and Togoland, seed is presoaked in cold water for 24 to 48 hours and sown in nurseries, which are generally provided with watering facilities.

In Trinidad, it has not been found necessary to treat teak seed to hasten germination as 90 to 100% germination is obtained without any treatment.[72]

Nurseries.

In India, the type of nursery used in different states follows climatic factors. Commonest is the temporary dry nursery, but occasionally one has watering facilities for exceptional years. Dry nurseries are usually situated in a part of the plantation site.

In West Bengal, Homfray (1935) says that small temporary nurseries in coupes can give all the plants required and prove cheaper and more effective, because the water required for temporary nurseries can be got cheaply by digging shallow wells. No pricking out is necessary and watering should be light. In Assam, treated seeds are dibbled in open nursery beds and watered profusely till germination commences. In Orissa, permanent nurseries have been abandoned in favor of dry rab nurseries in plantation sites. Seed is sown either in drills 9 in. apart or broadcast, but the former method is stated to give better results.[73]

In Madhya Pradesh and parts of Andhra Pradesh, permanent or semi-permanent nurseries with facilities for watering are in vogue. In Maharashtra, Kerala and Mysore, nurseries are generally situated within the year's plantation area at spots where soil and drainage are good, where the debris has been well burned; and occasionally, where emergency water is available. The nursery site should not adjoin a natural forest owing to adverse effects of shade and root competition. Ash found in the plantation area is mixed with the soil, clods of earth are broken, and weeds, roots and stones are removed. In North Kanara district, Mysore, soil for making the beds is dug only 6 to 9 in. deep, but in the drier parts of Madhya Pradesh and Andhra Pradesh digging to a depth of 3 ft. is considered necessary. It is customary to raise the beds from 4 in. to 1 ft. above ground level. In parts of Madhya Pradesh and Andhra Pradesh, however, the surface of the beds is sunk 3 in. below ground level to facilitate irrigation by flooding. An edging is generally constructed around the beds with split bamboo or other material in Kerala and Mysore.

Nursery Activities.

Size of beds. Four feet is probably the most suitable width and 40

[72] Letter No. R. H. 8/7/7, Dec. 3, 1969, from Res. Branch, Forest Division, Trinidad and Tobago.

[73] Silvicult. Res. Rep., Bihar and Orissa, 1942-43.

feet a convenient length. This standard size is generally followed in Tamil Nadu (Madras) and Kerala. Width of beds varies from 3 ft. in Travancore (Kerala) and parts of Mysore, to 6 ft. in Uttar Pradesh.

Covering the seed. Seed sown in nursery beds is in most places covered with ½ to 1 inch of earth. To aid germination, seed is sometimes covered with straw in Uttar Pradesh and Andhra Pradesh, or with *Phyllanthus emblica* twigs and straw in parts of Tamil Nadu.

Shading. Nursery beds are not generally shaded in Tamil Nadu (Fig. 7) and Kerala unless premonsoon showers hold off and hot weather persists. In Mysore beds are not shaded. In the drier parts of the Madhya Pradesh, Andhra Pradesh and Bihar shading is often necessary for the survival of seedlings during hot weather.[74]

Figure 7. *Typical teak nursery in Tamil Nadu, seeds sown in May to provide stumps for the rainy season planting of next year. Notice the edging for the beds.*

Watering. Beds are not watered in Mysore, and only rarely or under exceptional weather conditions in West Bengal, Maharashtra and Kerala. In Assam, nursery beds are watered daily for one month after sowing, while in parts of Uttar Pradesh, Bihar, Madhya Pradesh and Andhra Pradesh the beds are watered profusely until germination starts, and thereafter moderately until the monsoon sets in.

[74] Silvicult. Res. Rep., Central Provinces, 1924-25.

Fertilizing. Teak nursery beds, especially the temporary ones, are generally not fertilized, except for the ash mixed with the soil; leaf mold is added occasionally. Nursery beds do not retain their initial fertility even if leaf mold, wood ash and cow-dung are added or green manure crops grown, or the beds fallowed every alternate year.[75]

Sowing. Seed is sown from early February to April in Bihar, in April in Uttar Pradesh, West Bengal, Assam, Orissa, Tamil Nadu (Madras) and Coorg (Mysore), in the latter part of May to June, in Mysore, from April in Nilambur to June in Travancore (Kerala), and from March to June in Madhya Pradesh. Experiments in Hoshangabad district (central India) have indicated that late May is probably the best sowing time for that locality. The quantity of seed sown varies within wide limits from 1/40 to 1/25th lb. in Assam to 3 lbs. in Coorg per sq. yard. Experiments in Begur, Dhoni and Top-slip of Tamil Nadu have indicated that 25-30 lbs. of seed per standard bed (40 ft. x 4 ft.) gives the largest number of utilizable stumps per bed.[76]

Nursery transplanting of seedlings is not necessary; experiments in Talwara nursery in Madhya Pradesh indicated that nursery transplanting of seedlings at 6"x6" spacing results in a very large proportion of bushy-rooted, badly-shaped plants unfit for stumps.[77] In Upper Godavari division, Andhra Pradesh, unlike in Nilambur (Kerala), sowing seed in nursery beds at 4"x4" spacing has given better sized stumps than broadcast sowing. Teak plants in nursery beds are not thinned in West Bengal, Orissa, Travancore, Coorg and in parts of Maharashtra. Nursery transplanting of seedlings is practiced in Uttar Pradesh, Assam, Bihar and parts of Madhya Pradesh and Maharashtra.

Preparation of Stumps. Teak seedlings are prepared for planting by pruning off both the shoot and root. Generally 1 to 2 inches of shoot is retained, but in West Bengal shoots are pruned to ½ inch. Roots are normally pruned to 6 to 9 inches, but are left as long as 12 inches in Uttar Pradesh, Madhya Pradesh, Travancore (Kerala), and parts of Andhra Pradesh. Stumps of diameter less than 1/3 inch are not recommended for use, the upper limit being 3/4 inch, though in Madhya Pradesh, and parts of Andhra Pradesh and Maharashtra, stumps of 1½ inch diameter (in Assam 2 inch) are considered useful. Stumps more than 1 inch in diameter may be split lengthwise; survival of split stumps is equal to undivided stems. Splitting into 4 parts, however, usually impairs survival. Malformed stumps have survived as well and produced as good plants as normal ones.[78] In Tamil Nadu the best range of stump diameter to use is considered to be 0.4 to 0.8 inch. The number of usable stumps turned out per square yard of bed is said to be from 3 to 16 in Assam to 60-120 in Tamil Nadu.

75 Indian Forest Rec. (NS) Silviculture 4 (5).
76 Forest Res. Rep., Madras, 1944-45.
77 Silvicult. Res. Rep., Central Provinces, 1930-31.
78 Silvicult. Res. Rep., Madras, 1949-50.

Usable stumps can be produced from undersized plants of the first year by putting them back in the nursery after root and shoot pruning. In parts of Mysore and occasionally in Tamil Nadu, while digging up stumps for planting, all undersized and suppressed plants are left behind; these, together with a certain amount of dormant seeds may give fully stocked beds in the second year.[79]

Thailand.

Raised nursery beds are formed, about 8 inches high, with soil supported by split bamboo. Teak seed is sown in June at approximately 50 seeds per square foot, of which about 70 percent are expected to germinate. The seedlings are thinned to about 8 per sq. ft. of nursery bed. Nursery watering is done twice a week when rainfall is short. Year-old plants are reduced to stumps 8 inches long with a ½-inch long and thick shoot portion and 1- to 1½-inch thick taproot. Planting is done in April and through May. Stumps are planted in stake holes 2 meters apart, with 95 per cent or more success.

Trinidad.

Nursery beds are made four feet wide and, in July, seeds are sown in rows 9 inches apart with seeds 4-6 inches apart in them. Soil is generally hoed before sowing, and drains 12 to 15 inches wide are dug in between beds. Nursery transplanting is not done, but the plants are reduced in number to obtain a spacing of 6 inches.

Honduras.

Raised nursery beds are 4-6 feet wide. Nursery soil is 1:1 sand and loam, and seeds are sown broadcast and covered over with a ¼-inch layer of sand. Beds are profusely watered. Germination starts in 3 weeks and continues for 3 months. Seedlings are transplanted when they have 1 to 2 pairs of leaves, and leaf blades are trimmed back to their stalks to keep down transpiration. The plants are set 18 inches apart and irrigated with sprinklers. Watering is reduced during the last 3-4 weeks, to harden off plants. In 6-8 months, plants are 3-5 feet tall, and they are planted out as stumps in advance of the rainy season in May-June.

Stumps are prepared by cutting off the shoots while still in transplant beds at a height of 2 to 6 inches, and the roots in the process of removing the plants from beds to lengths of 8 to 12 inches; lateral roots are also trimmed. The root system is then dipped in clay slurry to prevent drying up, wrapped in burlap into bundles of 25-30 and stored for 2-3 days before outplanting.

Plantation Sites

Correct selection of site is of fundamental importance; it is "half the battle won", and a wrong selection, despite subsequent care, is almost certain to end in disappointment. The results of wrong selection may not appear for several years; early growth on lateritic soils, for example, is rapid but soon height growth practically stops

[79] Silvicult. Res. Rep., Bombay, 1939-40, Pp. 36-37.

and the area is invaded by evergreen species. Teak planting localities in India have a wide range of climatic conditions, with rainfall varying from about 30 to 200 inches. Selection of site is thus largely a local problem keeping in view soil and other requirements of teak.

Soil requirements of teak have been detailed in an earlier section. Drainage is one of the limiting factors and a fairly deep, well drained soil is essential; soils with poor drainage, water-logging or salinity are unsuitable. Steep slopes are generally unsuitable but moderate slope is quite good, especially where soil is from gneisses, schists or trap. Well-drained deep alluvium is the most suitable soil for teak all over India and, in Assam, also the deep red clay of lateritic origin. Laterite or laterite gravel should be avoided, as also clays, black cotton soils and light sandy and gravelly soils, particularly those derived from sandstone.

Soil flora and existing forest growth even if natural teak is present, are rarely adequate guides, and are often misleading. Teak can be successsful on some ground where it is not found naturally, even within its zone of distribution. Areas of stunted forest or those with dense grass cover should be avoided. In some parts of India the presence of bamboos, especially *Dendrocalamus strictus* is regarded as an indication of suitable sites. Indicators of unsuitable sites are imperata grass, preponderance of *Xylia*, stunted *Anogeissus latifolia*, abundant *Terminilia tomentosa*, *Phyllanthus emblica* especially in pure patches, and the presence of swamp species like canes and *Alpinia*. In Madhya Pradesh and in parts of the Deccan the presence of *Butea frondosa* and *Careya arborea* indicates ill-drained soils where teak is not likely to attain good size.

It is generally stated that the presence of well grown plants of *Indigofera tinctoria* is indication of good teak soils, but there is no experimental evidence to substantiate this. Champion says that in Burma. *Strobilanthes* which makes an ideal undergrowth to teak, indicates a good second class teak locality, on sandy flats near

Figure 8. *Teak plantation on site prepared by clear-felling and burning; established by planting "stumps", which are nursery-grown seedlings from which tops and roots have been pruned.*

streams.[80] Grieve says that presence of the bamboo *Dendrocalamus membranaceus* is not an indication of good teak soil.[81]

Preplanting Operations

Success of a plantation is governed largely by the proper timing of preplanting operations. Varying rainfall conditions in different parts of India, Burma and other countries necessitate local schedules. In general, for areas in the Northern Hemisphere having a summer monsoon commencing in June, all fellings should be completed before January, first burning and re-burning of debris by February 15 to April 1 and aligning and staking by April 1 to May 15. Stump planting should be completed as early as possible after the first, adequately heavy premonsoon or early monsoon showers (Fig. 9). In Bihar, teak is sometimes planted 1 or 2 years before felling the overwood.

Figure 9. *Teak plants 3 weeks after the break of the rains. Stumps were planted April 7-17 during pre-monsoon rains, after clear-felling heterogeneous forest. Tamil Nadu.*

The following indicates the time table of operations in Indian States:

	Completion of rubbish felling	Burning	Aligning and staking
Uttar Pradesh	April-May	April-May	Along with planting, generally
Assam	January-March	March-April	March-April
Bihar	December-January	March-May	April-May
Orissa	January	February-April	April-May
Madhya Pradesh	February-March	April-June	May-June
Maharashtra	December-March	March-May	April-May
Coorg (Mysore)	January-March	March-April	April-May
Travancore		April	April-May

80 H. G. Champion, Burma Tour Notes, 1926.
81 J. H. A. Grieve, Insp. Notes, Bhamo Forest Division, Burma, 1919.

Planting

Stumps are planted without soil preparation in holes made with a crowbar, bamboo or wooden stick or a **dah** (curved knife). In Uttar Pradesh, Gujarat, and Maharashtra stumps are often planted in pits, but experiments in the coastal districts of Kerala have shown that, for this locality, pits have no advantage over stake holes; [82] in the southeast coastal districts of Tamil Nadu which are drier, pitting has increased height growth.

Stumps are generally buried up to the same level at which they grew in the nursery, except in Orissa, where the tip of the shoot is planted flush with the ground. Particularly in the drier districts of Tamil Nadu (Fig. 10), the latter method increases height growth and survival percentage.[83] Stumps should be firmly planted, the soil consolidated by hand or foot, or by driving the crowbar or stake into the ground close to the stump and levering it away from the stump.

Figure 10. *Teak, planted 12x6 feet apart, in a bamboo area. This planting distance results in branching of the stems before the canopy closes up. Angul Division, Orissa.*

Spacing.

The 6x6 foot spacing is the most common all over India, but wider spacings are also used. In Uttar Pradesh, teak is spaced from 6x6 to 10x10, and 10 to 15 feet apart in taungya crops. In Bihar, spacing is generally 8½ by 8½, but 12x6, 8x8 and 6x6 foot spacings are also

[82] Indian Forest Rec., (N. S.) Silvicult. 3 (3).
[83] Silvicult. Res. Rep., Madras, 1939-40.

used. In parts of Kerala and Tamil Nadu teak is planted at 8½x8½foot spacing on superior sites. This wider spacing results in better height and diameter growth than 6x6 foot spacing, and reduces nursery, planting,weeding, and early thinning costs. It also facilitates intercultivation of agricultural crops and has not encouraged low branching or formation of epicormic shoots. On best sites at Nilambur, trees spaced at 6x6 feet can be suppressed by overcrowding before the first mechanical thinning is done at the age of 3 years, when the crop would be about 25 ft. high. On site quality II low, III and IV (1964 Yield Table), however, the 6x6 foot spacing is satisfactory.[84]

Teak is planted in the North Kanara divisions of Mysore and in Gujarat at 9x9 feet in large plantations, at 6x6 feet in **rabs** (small regeneration clearings) or pole forest areas; at 12x9 and 12x6 feet in taungyas, and in lines 18 to 22 feet apart in Satpura teak poles areas. In Orissa, teak is sometimes planted in rows 33 feet apart and spaced 6 or 9 feet apart in the row, especially in areas where bamboo (*D. strictus*) has flowered gregariously (Fig. 10). Planting under the forest canopy some years ahead of fellings has been tried in Uttar Pradesh, Bihar, Orissa, Madhya Pradesh, Andhra Pradesh and Maharashtra (Fig. 11). Such planting is unsuitable for wetter forests

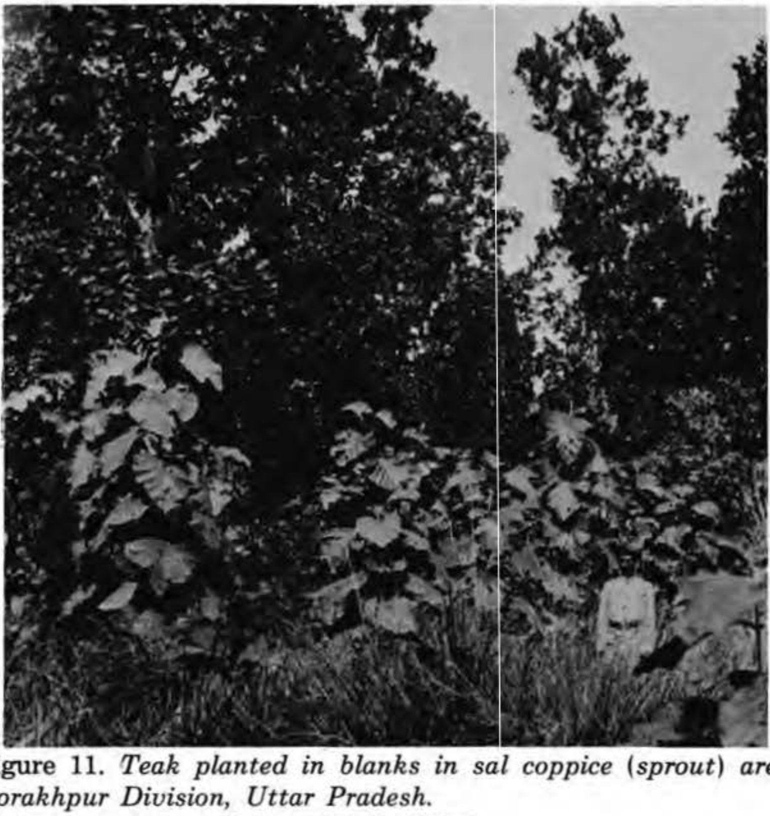

Figure 11. *Teak planted in blanks in sal coppice (sprout) areas, Gorakhpur Division, Uttar Pradesh.*

[84] Silvicult. Res. Rep., Madras, 1949-50, 1950-51.

but more suitable for drier ones. Planting or sowing in flowered bamboo areas has also been done. In Orissa, teak was planted in *Denrocalamus strictus* flowered areas in lines 33 ft. apart and the plants 9 ft. apart in the lines. In Tamil Nadu, Mysore and Andhra Pradesh, sowing or planting of flowered bamboo areas has been tried.

Information on spacing in other countries is condensed below:

Country	Spacing	Remarks
Burma	6 x 6 feet	
Ceylon	10 x 10 feet	
West Malaysia	8 x 9 feet	Earlier plantings at 10 x 10 or 10 x 20 foot spacing resulted in heavy and persistent branching, premature terminal flowering and slow height growth; ideal planting distance is believed to be 8 x 8 ft. but 8 x 9 ft. has been adopted to facilitate mechanical cultural operations.
Java	3 x 1 meters	This is the usual planting distance for average sites; others are 2 x 1 and 3 x 2 meters. Stocking is by sowing 5 seeds per hole.
Thailand	2 x 2 meters	
Cambodia	2 x 2 meters 3 x 1.5 meters 4 x 1 meters	Initial stocking is by sowing seed; failures are replaced by stumps (root and shoot cuttings).
Ivory Coast	2 x 2 meters	
Ghana	6 x 6 feet	Stumps
Togoland	2 x 2 meters 2.5 x 2 meters 2.5 x 2.5 meters	Stumps
Dahomey	2 x 2 meters	
Nigeria	8 x 8 feet 7 x 7 feet 9 x 9 feet	Southern states Northern states Northern states
Kenya	6 x 6 feet	Stumps
Tanzania	6 x 6 feet	Stumps
Uganda	6 x 6 feet	Stumps
Zambia	9 x 9 feet	Formerly 6 x 6 feet; stumps
West Indies (St. Vincent)	6 x 6 feet	
Trinidad and Tobago	6 x 6 feet	Increased provisionally to 7 x 7 feet since 1967.
Panama	2.5 x 2.5 meters	

Honduras	6 x 6 feet	Teak first introduced in 1927 at Lancentilla near Port Tela, probably from seed of Burma origin, obtained from Trinidad.

Replacement of Casualties.

Dead stumps should be replaced as soon as possible; late July is generally considered the latest date for safely replacing causualties in most parts of India. In Burma, replacement may be successful up to middle of August and in Travancore (Kerala) up to middle of October. In Uttar Pradesh, Orissa, Andhra Pradesh, and occasionally in Mysore casualties are replaced also in the second year, but in moister localities such replacements do not catch up with the rest of the crop.[85]

Irrigated Plantations

In North Coimbatore division, Tamil Nadu, irrigated plantations have been formed, in a scrub type of forest, on a small scale (Fig. 12). Irrigation is done 2 to 3 times a month up to 5th or 6th year by percolation from shallow trenches which run between the lines of teak.

Figure 12. *Teak plantation, 8 months old, irrigated by percolation from shallow trenches; average height 8 3/4 feet. Hulikadoorg, North Coimbatore Division, Tamil Nadu.*

[85] Silvicult. Res. Rep., Madras, 1939-40, p. 49.

Experiments have shown in general that, before the first growing season, irrigation once a week is better than once a fortnight, and that after the first growing season there is no significant difference between them. In 1942-43, irrigation by percolation, once a month for 3 consecutive days of 8 hours each (24 hours per month) was better than irrigation of the same kind once a week for 3 hours each week (12 hours per month), and once a fortnight for 3 hours (6 hours per month) but, in the next year (1943-44), the advantage of watering once a month for 3 consecutive days also disappeared; however, at the end of the first growing season this level of irrigation resulted in the best height growth. In all these cases, by comparison, the unirrigated control was significantly poorer both in height growth and survival percentage. It was also found that the effect of irrigation was felt through the fifth year but, during the 6th year its influence was very small. As for method of irrigation, percolation from shallow trenches is easier, cheaper and just as effective as irrigation by flooding.[86]

Weeding and Early Culture-Tending

Teak plants are very susceptible to competition for available moisture and nutrients by roots of grass and weeds. Teak plantations are generally weeded three times in the first year, two in the second and once or twice in the third year.

First year weeding and tending.

Teak should be out-planted as early as possible in the growing season; this speeds height growth, facilitates competition with weeds and minimizes weeding costs.

Four types of weeding are in common use: (1) fork weeding, in which surface soil is overturned and clods broken up, (2) scrape weeding, in which the weeds are scraped off, (3) weed pulling, in which weeds are uprooted by hand, and (4) weed cutting, in which weeds are cut at ground level. Fork weeding is the most expensive and weed cutting the cheapest. Experiments in Tamil Nadu and Kerala indicated that, in general, "fork" and "scrape" weedings give better results than weed cutting; the effects of different weeding treatments in the first year disappear permanently by the end of the second. In South Coimbatore, Nilambur and Palghat divisions, results did not justify the extra cost of weeding a plantation in the first two years by 4 foot wide forking instead of 4 foot wide scraping. In the majority of divisions of Tamil Nadu and Kerala weeding is done in 4 ft. wide strips.

The following statement shows first-year weeding practices in several Indian states:

[86] Silvicult. Res. Rep., Madras, 1944-45.

State	Weedings		
	Number	Type	Month
West Bengal	3	Weed pulling around plants.	
Assam	2 or 3	Strip weeding.	
Bihar	3	Weed cutting around plants.	
Orissa	2 or 3	Weed cutting in 4 foot wide strips.	
Madhya Pradesh	2 or 3	Weed pulling around plants.	First: July, Second: August, Third: Sept.-Oct.
Maharashtra	2 or 3	Weed cutting and earthing up around plants.	
Mysore (N. Kanara and Dharwar)	2 to 4	Weed pulling and mulching, and earthing up around plants.	First: July-Aug., Second: October. Third: November.
Mysore (Kakankote)	3	Weed cutting in strips.	
Kerala	3 to 6	Usually scrape weeding.	
Tamil Nadu (Madras)	3 to 6	Usually scrape weeding.	

In Burma, weed cutting is done over the whole plantation area, while in Assam, Tamil Nadu, Mysore and parts of Maharashtra, weeding is limited to strips. In other places weeding is done in small circles around plants. As regards timing the weedings, the maxim must be to keep the plants free from weeds during the growing season.

In general, in India, weeding time is May-June, July-August and September-October in the moister types of forest and one month later for each weeding in the drier types. Second weeding is generally the most expensive.

In Assam, Orissa, Madhya Pradesh, Gujarat, Maharashtra, Mysore and Kerala, bamboo regrowth is a serious problem in plantations, especially those not well burned. Bamboos concerned are *Melocanna bambusoides* and *Dendrocalamus hamiltonii* in Assam; in Orissa it is *Bambusa arundinacea; D. Strictus* in Madhya Pradesh and Andhra Pradesh, and *B. arundinacea* and *D. strictus* in Maharashtra, Mysore, Tamil Nadu and Kerala. Cutting bamboo is done in some states up to the 6th year or later. Imperata grass (*Imperata cylindrica*) is a problem in many states, and it has to be grubbed out or kept well weeded, especially in Tamil Nadu and Kerala. It smothers young teak and arrests its growth, and becomes a fire hazard during dry months. In Assam, the effects of grass are reduced by intensive weeding and grubbing, and by close planting to ensure quick closing of the canopy.

Weeds troublesome to young teak but easily shaded out by a closed canopy are *Eupatorium odororatum* and a naturalized lantana. The former, serious in Assam and West Bengal, requires repeated weedings. The lantana, a pest in several states of southern India, can be controlled by a good initial burn, but may reappear and seriously retard growth after thinnings.[87] Among other weeds are *Hybiscus* (Tamil Nadu and Kerala), *Ageratum, Calycopteris* and *Mucuna.* They are controlled by repeated cutting and uprooting. For grassy areas scrape weeding is effective.

Efforts to control weeds by introducing ground covers found useful in rubber plantations, including *Dalbergia sissoo, Leucaena glauca, Tephrosia candida, Pueraria Javanica,* and *Calapagonium morsonoides,* have met with little success.

Against all weeds, chemical weedicides, a number of which are on the market, are effective but the cost incurred may not be always justifiable.

Second and third year weeding and tending.

During its second season, teak is usually weeded once or twice between May and September; occasionally a third weeding is necessary. Weedings include climber cutting, cleaning, cutting back of bad teak stems and removal of double leaders. There are generally two second-year weedings in West Bengal, Bihar, Tamil Nadu, and Mysore, one to three in Assam, and one to two in Madhya Pradesh, Andhra Pradesh and Maharashtra. Scrape weeding in grassy areas and vigorous cutting back of bamboo may be essential. Weeding is not generally done in the third year, except in Mysore, Maharashtra and Kerala where generally one weeding is done, and in Travancore (Kerala) where two weedings are done. In all states, however, one operation of cleaning and climber cutting including cutting back of bamboo regrowth is essential. Sometimes in Wynaad (Kerala) three weedings are done in the third year. In the fourth year, cleaning and climber cutting are done in Assam, Orissa, parts of Maharashtra and Gujarat, and Travancore (Kerala).

The number and intensity of weedings must vary with rainfall, locality, method of formation (sowings or stumps, etc.) and weed conditions. Experimental work is needed to determine the intensity, type and appropriate date of weedings in each locality.

Climbers.

Generally speaking, climbers are not a menace in young teak plantations if they are kept suitably weeded, cleaned and thinned,

87 Silvicult. Res. Rep., Madras, 1950-51.

but they could destroy young teak if weedings be neglected. Each thinning operation is preceded by cleaning and climber cutting.

Pruning teak plantations.

Experiments in Nilambur have shown that pruning side branches of saplings each year up to the height a man can reach, till the year of first thinning, is not beneficial to teak as it does not produce increase in height growth, nor is there any disadvantage from pruning like production of epicormic branches.

Regeneration with Taungya

Taungya essentially means the raising of a forest crop in conjunction with an agricultural crop. This century-old system is, perhaps, the outstanding contribution of Indian forestry to the advancement of tropical forestry around the world. It is the accepted system for establishing teak plantations in Uttar Pradesh, West Bengal, Kerala, Assam and Tamil Nadu, and is used at least occasionally in Orissa, Madhya Pradesh, Maharashtra and Mysore.

The system varies slightly from country to country, but usually the cultivation of the field and forest crops is a joint effort of the landowner, generally the government, and a private farmer; it is feasible only where there is demand for cultivable land. Clearing of site, burning, staking and preparation of the ground for teak planting, are generally done by cultivators under an agreement with the Forest Department. Efficient burning of slash is important for success. Teak is introduced by stump planting or, in parts of Madhya Pradesh, Andhra Pradesh, Burma and Java, by sowing teak seed. Trees or seed spots are in rows 15 feet apart in Uttar Pradesh and Madhya Pradesh, where they are usually cultivated by plowing. In Assam, Orissa, parts of Maharashtra and in other states where hand cultivation is usual, teak spacing may be as close as 6 x 6 feet.

The commonest field crops used are rice, cotton, maize, sesame and, in some states, wheat, ragi (*Eleusine corocana*), pigeon pea (*Cajanus indicus*), and various vegetables. Experiments in Tamil Nadu and Kerala have shown that the following crops are suitable for growing with teak; hill rice, chillies, tapioca, ginger, horse gram (*Dolichos biflorus*), and ragi. Less suitable in many areas are cotton, sesame, maize and pigeon pea. Usually unsuitable are irrigated rice, sugarcane, plantain, jute, creeping vegetables like pumpkin and cucumber, yams, cocoyam (*Amorphopallus*), and eggplant (*Brinjal*).

It is useful to get teak started as soon as possible before the field crop is introduced. The field crop is not usually allowed to grow within a foot or foot and a half of teak. During the growth of the field crop, weeding and tending of teak is done by cultivators. In Tamil Nadu and Kerala, rice plants are uprooted or pressed back to a distance of 2 feet from each teak plant. After the field crop is harvested, the stubble is allowed to remain in the ground except where a second field crop has to be sown, when it is extracted early in the next hot weather. In Tamil Nadu and Kerala, after harvest, weeds are cut from 4-foot wide lines two or three times between late August and the following January. A second crop is usually grown in Uttar Pradesh, West Bengal and Travancore (Kerala). Usual heights of teak at the end of the first growing season are:

State	Height, feet
Uttar Pradesh	4 - 6
West Bengal	2 - 6
Assam	3 - 6
Bihar	2
Orissa	1
Madhya Pradesh,	1 - 2
Andhra Pradesh	1 - 2
Maharashtra, Mysore	1 - 6
Tamil Nadu, Kerala	4 - 6
Burma	1 - 3

In Uttar Pradesh, Orissa, and Madhya Pradesh and sometimes in parts of Tamil Nadu and Kerala, field crops are grown in the second year also. Except in parts of Maharashtra, Mysore and Kerala, second year weeding and tending are done by cultivators. Forks and double leaders are then removed, and in Kerala and Tamil Nadu also scraping round backward plants is done during one of the weedings. Casualties are replaced in the second year in Uttar Pradesh, Assam, Orissa, Madhya Pradesh, Andhra Pradesh and Burma. In Madhya Pradesh, with wide spacing of teak, a field crop is occasionally raised even in the third year, in which case the cultivator removes double leaders from teak, cuts *Eupatorium*, bamboo regrowth and regeneration of weed trees. If no crop is grown in the second or third year, necessary tending is done by the forest staff.

In West Bengal, Assam (Fig. 13), parts of Tamil Nadu & Kerala, it

Figure 13. *Teak plantation in Mowgong Division, Assam, 15 months old; planting distance 6x6 feet, height 12 to 15 feet.*

is considered that taungya teak crops are not so good as those raised without taungya; in Uttar Pradesh, Orissa, Maharashtra, and parts of Mysore and Kerala (Travancore) teak raised with field crops is considered better. In Tamil Nadu and parts of Kerala, in the first year, field crops reduce height growth of teak. This would, however, depend upon how much earlier than the field crop teak is introduced.

Plantations raised by taungya are cheaper, except in places where, owing to want of demand for agricultural land, high scales of wages have to be given to the farmers for their work. Moreover, weed growth is greatly reduced by taungya. Taungya plantations have less undergrowth than those raised without taungya, because of frequent cultivation. Undergrowth could be induced to appear later on by suitable manipulation of the teak canopy.

Taungya in other countries.

The taungya system is also practiced in East Pakistan, Ceylon, Malaysia, Thailand, Java, Cambodia as well as in some countries of Africa and the Western Hemisphere. In East Pakistan, teak is introduced in the Chittagong Hill Tracts with taungya, locally called "jhum," by planting year-old teak plants root and shoot pruned to 9 in. and 3 in. respectively. Weeding and tending are done for 2 to 3 years. In Java, one field crop is planted before teak is introduced, and field crops are grown for two to three years thereafter. In Thailand, wherever demand exists for cultivable land, teak is introduced with taungya by planting stumps; elsewhere, plantations are formed departmentally by employing laborers. In parts of West Africa, e.g., Ghana, Togoland, etc., taungya is practiced with restrictions on the planting of field crops like plantain and cocoyam considered harmful to teak.

In Nigeria, teak is raised with taungya because the farmer is unable to maintain soil fertility by any other method except bush fallow. Taungya is also the cheapest method of forming a plantation. The cost of planting at 8 x 8 feet without taungya is about 100 man days per acre to the third (without overhead) compared to only 50 with taungya. In the Western Hemisphere taungya is practiced in Trinidad, Honduras and some other places; land is leased to farmers for 12 to 18 months, and teak stumps are raised and planted by the forest department.

In Trinidad, the common field crops are rice and corn (maize), and two crops are raised in 12 months after teak is planted. Plantation area is cleared by timber contractors and charcoal burners. The taungya farmer introduces a maize crop in October in wet areas, and in the following June in dry ones. Maize is reaped in February-March, the corn stalks burnt along with the forest and a hill rice crop is sown in June.

Planting of teak stumps with 1 inch of stem and 5-6 inches of root is in June, and selected stumps of not less than 1 inch diameter are planted 6' apart, with generally 90 percent expected survivals, the blanks being refilled in August.

Early growth of planted teak is stated to be better in drier areas, (with less than 80 in. rainfall), owing to better forest clearing and more thorough burn. On heavy clay soils in wetter areas, weed growth is extremely heavy and cost of establishing a plantation is considerably higher.

The plantation is cleaned once between the second and fourth years, first thinning done in the fifth year, which reduces the stocking to 600 trees per acre, then thinnings follow at 5 year intervals up to the 20th year, and as required thereafter. Understory of leguminous shrubs and trees is encouraged during the periodical cleanings.

Mixture and Underplanting in Teak Plantations

All available information on the question of disadvantages arising out of pure teak plantations indicates that these cannot be ascribed in particular to species purity, and cannot be cured by growing mixed crops. No single species has been found to form a satisfactory crown mixture, indeed most are harmful. Mixtures in strips or groups, again, do not reduce appreciably insects damage to teak; and in their case difficulties arise in tending. Therefore, mixtures cannot be recommended straightaway as palliatives for the disadvantages of pure plantations. Some underwoods of even age with teak have shown promise, though they do not benefit teak.[88] It has been shown in Tamil Nadu and Kerala that underplanting is possible and beneficial. A useful understory to teak has been raised successfully by underplanting bamboos like *Caphalostachyum pergracile, Thyrosostachys oliveri, Bambusa polymorpha* and trees like *Pericopsis mooniana* and *Swietenia macrophylla. Hopea parviflora* underplanting has also been tried.

It has not been found advisable in Java to plant teak in mixture with other tree species because: (1) their crowns get crowded out quickly, (2) teak is sensitive to root competition, (3) teak branches heavily in mixed stands. Interplanting with *Leucaena gauca* has been advocated because it is a green-manure crop and supplies nitrogen, keeps out weed growth and prevents soil erosion; however, it has been emphasized that *Leucaena* should be prevented from overtopping and suppressing teak. *Leucaena* has also been claimed to improve soil structure by providing mulch, make for balanced phosphate nutrition, and enrich soil humus (Van Alphen De Veer, 1957).

[88] Silvicult. Res. Rep., Madras, 1950-51.

Undergrowth.

This is desirable for preventing soil erosion under pure teak, in controlling defoliation and maintaining soil fertility. As introduction of undergrowth artificially is likely to be expensive, it is advantageous to encourage any existing natural undergrowth as is done in some states, notably Mysore (Kadambi, 1945).

Thinnings

The majority of India's teak plantations being less than half rotation age, in many states experience of later thinnings is meager. The best site quality of India's teak plantations, excluding Burma, is slightly better than the II quality of Burma. Only on restricted patches in Nilambur does teak growth approach the best Burma quality.

The following site qualities have been estimated by the India-Burma Yield and Stand Tables of 1940 and the India table of 1964.

State	India-Burma Yield Table 1940	India Yield Table 1964
Uttar Pradesh	II to IV	I to III
Assam	II to IV	I to III
Maharashtra	IV and below V	III to below IV
Madhya Pradesh	IV and V	III to below IV
Orissa	II to IV	I to III
Mysore	III/IV, IV & V, average quality IV and below	Average quality III/IV and below
Coorg (Mysore)	IV to V	III/IV
Kerala (Nilambur)	Average quality III/IV II to IV and below	II/III to III and below

Early thinnings.

Early thinnings are needed to foster the crown development necessary for optimum growth of teak. Because optimum crown diameter is related to tree height, thinning to provide space for crown expansion is scheduled on the basis of height of the crop. In Kerala and Tamil Nadu the first thinning is done in the 3rd, 4th, and 5th year, according to quality, which roughly corresponds to heights of 25 to 30 feet. The second thinning is done in the 6th, 8th or 10th year, and the third from the 10th to 18th year according to site quality. In other states first, second and third thinnings are normally done at the ages detailed below:

State	First thinning (years)	Second thinning (years)	Third thinning (years)
Uttar Pradesh	5	10	15
Assam	5	10	15-20
West Bengal	4-5	8-10	13-15
Madhya Pradesh	6-10		

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Mysore	III/IV, IV & V, average quality IV and below	Average quality III/IV and below
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State	First thinning (years)	Second thinning (years)	Third thinning (years)
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Assam	5	10	15-20
West Bengal	4-5	8-10	13-15
Madhya Pradesh	6-10		

Orissa	5 (for 6'x6' spacing), 6 (for 8' spacing), 8-10 (for 6'x12' spacing)	10 (for 6'x6' spac-spacing)	
Coorg (Mysore)	8	10-14	15-20
Travancore (Kerala)	9	14	19
Mysore (N. Kanara forest divisions)	6 - 7 (6'x6' spacing), 8-9 (9'x9' spacing)	11-12 (for 6'x6' spacing) 15-17 (for 9'x9' spacing)	17 (for 6'x6' spacing) 20 (for 9'x9' spacing)
Maharashtra (Thana, etc. divisions)	10 to 15 (depending upon vigor and planting spacing)	10-20	20 to 40
Kerala (Nilambur and Wynaad divisions(	3	6	10
Tamil Nadu (South Coimbatore division)	4	8	13

The following thinning regime has been suggested by Sagreiya (1957) for Madhya Pradesh plantations:

Teak-Thinning Regime,Madhya Pradesh

Thinning	Age, years Good quality	Poor quality	No. of trees per acre	Crop diameter (in.)
First	5	10	500	2.0
Second	10	20	300	3.5
Third	20	40	200	5.0
Fourth	40	60	120	7.0

Kind of thinning.

The first two thinnings are generally mechanical and each aims at removal of 50 percent of the stems. In the states of Southern India, they may be deferred or reduced in intensity to keep down grass or weeds. Where original spacing is 6 x 6 feet, the crop should first be thinned when 10 to 25 feet high. The second thinning should be made when height is 25 to 49 feet. The third thinning will be governed by the average diameter of the crop and, except in rare instances, is not mechanical. Teak responds well to heavy and early thinnings to anticipate, not follow, suppression, as advocated by Dr. Craib for wattle in South Africa. Timber from such trees, though fast grown, has been found equal in strength properties to timber from control plots subjected to the usual, (D-grade) thinnings (Table 2). Trees in "Craib's" plots have also developed clean stems up to heights of 30 to 40 feet as in control plots. Craib's thinning method is probably more advantageous to teak than the current practice, and should produce marketable timber (19 to 23 inches dbh) in 30 to 40 years. The average dbh of teak trees in Craib's thinning plots at age 16 years was 13.4 inches; average height was 82 feet. In the plots thinned to the usual D-grade, on the other hand, the average dbh was 9.7 inches and average height 73.7 feet.[89]

Climbing vines are cut at the time of marking or during the thinning. In Assam damage by the canker grub brings about uneven stocking, and this is corrected by the early thinnings.

Later thinnings.

In Kerala and Tamil Nadu, with well managed plantations in their advanced stages over large areas, recent working plans provide for an increasing thinning cycle with increasing age, the 4th, 5th, and 6th thinnings being in the 18th, 30th, and 44th years in Nilambur, and 22nd, 34th and 48th years in Malabar and South Coimbatore. Thinning intervals must vary to suit the silvicultural requirements of teak crops, whose needs, varying with their development, are governed by site quality.

The time intervals, suitable for the 3rd and later thinnings, are 5 years for crops between 5 and 20 years old, 10 years for crops between 10 and 40 years, 15 years for crops between 40 and 60 years and 20 years for crops over 60 years. The concensus of opinion is that the age of the last thinning should vary according to crop quality from 35 to 50 years, and 40 to 60 stems per acre should remain after it, and to allow for natural deaths, perhaps an additional 5 to 10 percent (Kerala and Tamil Nadu).

Kind and grade of thinning.

Generally speaking, a strong light-demander like teak requires a heavy grade thinning, and a "D" grade is therefore generally the most suitable for plantation teak. Individual opinions on teak thinnings have varied greatly from person to person and time to time, and this would remain so until more experimental evidence becomes available. There has, however, been a fair measure of agreement on the following broad, more or less abstract, points:

(1) In a thinned plantation, the crop should look distinctly open, i.e. individual crowns should have clear space all around.

(2) Normally, trees with relatively the best crowns and stem form should be retained and evenly spaced, even at the sacrifice of some trees of good crowns and boles. All trees with poorly developed crowns and stems must be removed provided this

[89] Silvicult. Res. Rep., Madras, 1950-51.

will not result in permanent canopy gaps.

(3) Dying and diseased trees must be removed.

(4) During the third thinning, forked and misshapen trees which may remain over from the first two mechanical thinnings should be removed.

All thinnings should be checked against the standard of the All India Yield Table figures.

Rotation

The following rotations and breast height girths and diameters at maturity, generally based on site qualities, have been envisaged for plantation teak in Indian states:

State	Girth (feet)	Corresponding Diameter (inches)	Rotation Age (years)
Assam	6	23	60 - 80
West Bengal	6 to 8	23 - 30.5	80
North Bombay	3 to 5	11.5 - 19	65 - 80 (timber)
	2 to 3	7.6 - 11.5	40 (poles)
North Kanara,	6 to 7	23 - 26.7	120 (high forest)
Mysore	4-1/2	17.2	60 - 80 (pole forest)
Madhya Pradesh	4 - 5	15.3 - 19	80
Andhra Pradesh	6	23	70 - 100
Mysore (Shimoga. Kakankote and Coorg)	6	23	70 to 80
Tamil Nadu	6	23	70 - 100
Kerala (Travancore-Cochin)	6 - 7	23 - 26.7	70 - 100

SILVICULTURAL SYSTEMS IN TEAK FORESTS

As early as 1826, Dr. Wallich reported great stores of teak in the Burmese provinces of Martaban and Tenassarim, and advised operation by the government to keep the forests productive. Unfortunately, here as in parts of India, such advice was not followed, and many accessible regions were devastated under unsupervised leases.

It was not until 1852, that Lord Delahousie, Governor General of India and Burma, issued the historic document which placed the forest lands under public silvicultural management. Under Dr. D. Brandis, a young German forester, the system of forest reserves was increased, timber cutting limited to responsible contractors, and the number and size of trees to be cut was regulated. From such beginnings, silvicultural systems have been developed and adapted for the management of natural teak forests throughout its range.

Selection Systems

Earliest attempts to manage natural forests producing teak, both in India and Burma, usually took the form of diameter limit cuttings. Ill-adapted as the selection system is to the regeneration of this intolerant species, its practice has prolonged the production of teak from vast forest areas, and has afforded more than a century of experience as a basis for improved methods. With such modifications, individual tree selection remains basic to management of much of the teak forest of Southeast Asia.

Selection Felling System.

The silvicultural system applied to "High Forest" (as opposed to "Pole Forest") on the west coast of India, has been widely termed "Selection System" but, it is not the same system as practiced in European forests. It does not provide for the attainment of a normality of the forest, there is no guarantee of natural reproduction, and it does not always take the silvicultural requirements of teak or its main associates into consideration.

Cutting of all or a large proportion of the mature teak and other preferred trees is bound to lead to a diminution of the stock of these species. Thus, the India-Burma selection system has been called by some the "mining system" of forestry. For natural forest, however, where teak and other merchantable species are too small a proportion of the crop to justify clearfelling, it is difficult to envisage any approach more appropriate than the time-honored selection system.

In the selection system, as practiced in India and Burma, trees of teak and other merchantable kinds which have attained the exploitable size, and are not otherwise required as seed bearers or to prevent overfellings, are selected for felling. The exploitable size in India varies within wide limits, and ranges from a girth of 4 to 4½ feet (15.3 to 17.2 in. diameter) in pole forests to 6 to 7½ feet (23 to 28.7 in. diameter) or more in some high forests. The age (100-150 years) corresponding to this exploitable size is estimated by ring counts. This age is divided into a convenient number of "periods" or felling cycles, varying by localities but often 30 years in length. During this period, fellings go round the whole area once. Often, this "felling cycle" is divided into subperiods of 5 or 6 years and the boundaries of the corresponding subperiodic blocks are laid out on the ground. This facilitates planning and equalizing of annual yields. The cut is fixed by number of trees, occasionally with a volume check. In North Kanara (Mysore) and Burma, teak trees are girdled two or three years ahead of the felling. The success of such cuttings in regenerating teak depends quite largely on the special methods, such as weeding, burning or patch planting, which accompany them.

Since about 1920, the India-Burma selection system has been gradually superceded by clearcutting, burning and stump planting (Tamil Nadu, Mysore, parts of Maharashtra) or, where possible, by natural regeneration through coppice.

The residual forest in each working circle, however, has to await its turn for conversion and continues to be worked generally in all the states under the selection method of fellings. Many forests previously worked under the selection system, and in which the proportion of marketable woods, especially teak, is small could be greatly improved by replacing the unsaleable trees with teak and without undue risk of insect or fungus attacks.

Improvement Fellings.

Improvement felling is a term applied, sometimes loosely, to the fellings done in forests being prepared for a more concentrated system of treatment, or in crops where over-exploitation has left only a low proportion of valuable trees. These fellings may be either of the "selection" type, where the inferior woods are felled over a felling cycle, to favor the more valuable ones, or of the "cleaning" type, in which unwanted, and damaged stems or bamboos are removed to induce or establish new regeneration. This operation includes climber cutting, thinning and other operations meant to improve the valuable trees, notably teak. Improvement fellings of the selection type are practiced in parts of Madhya Pradesh, Maharashtra (Bombay) and Tamil Nadu (Madras). These fellings are carried out under a definite felling cycle, by allotting the forests subjected to this system of treatment to an "Improvement Working Circle."

Recent working plans in Maharashtra have attempted to improve the residual growing stock, after a selection felling by improvement fellings, combined, where necessary, with clearfellings followed by planting. Also, where conditions are favorable, canopy underplanting ("diffuse planting") is practiced.[90]

[90] Revised working plan for the Thana forests, N. E. and W. Thana Working Circle, 1953.

A so-called "Uniform system" has been introduced in the Kanara East Division (Mysore). In the first, or preparatory stage, (20 years), fellings are confined to dead, dying, unsound or malformed trees, and open patches are planted. In the second stage, the forest is subjected to "final conversion fellings" and artificial regeneration. The system is thus more of the nature of improvement fellings supported by artificial regeneration on a large scale.[91]

The better quality teak forests of Burma have been largely treated under selection fellings on a long rotation varying from about 120 to 175 years, divided into felling cycles (Girdling cycle) of 30 to 35 years; the exploitable girth was 7 to 7½ feet in moist and 6 to 6½ feet in dry forests, and yield was often fixed by the number of trees.

Since the early 1900's fire protection in moist teak forests of Burma has been questioned because undergrowth impeded regeneration of teak. Fire protection was therefore given up save in the very young, new woods, and a practice termed "early burning" was adopted.

Clearfelling with concentrated artificial regeneration of teak and *Xylia dolabriformis* with the help of taungya is prescribed and practiced. Improvement fellings have been of two types: "O" fellings for the benefit of the old crop which is left behind after the selection fellings and "Y" fellings for the benefit of the yound growth.[92,93] What are called "amelioration fellings" to favor the principal species include thinnings, weedings and the removal, whether sound or unsound, of immature and mature trees to make way for the future crop.[94]

Silvicultural operations used to obtain natural regeneration of teak in Burma include:

Shelterwood system. Tried in the dry-deciduous forests of Shwebo division, the method essentially consisted of judicious opening up of the canopy by removal of teak and other mature trees and repeated cutting of bamboos. The method proved costly and results incommensurate.

Selection system. Teak trees of expolitable size and/or smaller size, if defective, are girdled and felled two to three years later, followed by improvement fellings. Results were not adequate on account of bamboo shade which keeps down teak.

Improvement fellings. Carried out after extraction to extricate saplings, poles and immature trees from overhead shade of worthless trees, but without cutting bamboos. Improvement

91 Working plan for the high forests of Eastern Division, Kanara.

92 Working plan for Shwebo Forest Division, 1937-1938 to 1946-47.

93 Working plan for Thaton Forest Division, 1935-36 to 1944-45.

94 Working plan for the Kyan and Kawdun working circles of Yau Forest Division, 1933-34 to 1942-45.

fellings were of two denominations. "Y" aimed at inducing recruitment, and "O" for fostering existing advance growth.

In recent years, saleable non-teak is first cut, then teak, followed by improvement fellings, and this is believed to be an improvement on past methods.

Utilizing gregarious flowering of bamboo. Accompanying a gregarious bamboo flowering, overhead non-teak trees are removed resulting in stocked patches of teak.

Teak has been harvested in Thailand for over a hundred years without much systematized management. Demonstration forests, the first with an area of close to 500 acres, have been organized. A rotation of 120 years is envisaged. Selection fellings are governed by exploitable size and a felling cycle of 30 years. Five 30 cm. girth (6.25 in. diameter) classes are recognized, the largest class being 200 plus cm. gbh. (25.45 in. dbh). Trees under 100 cm. gbh. (12.7 in. dbh) are not felled; and fellings are more conservative on better quality sites and restricted to 85 percent of the exploitable volume. The approximate average volume extracted annually from 1956 through 1966 has been estimated at 2.67 million cubic feet (Kaufman, 1968).

Elephants are employed for dragging timber from felling areas and lotting in timber depots. Trucks do the rest of the hauling.

Coppice Systems

Because teak sprouts prolifically, early silvicultural systems depended largely on coppicing for regeneration. In the past, coppice systems, variously modified to suit local situations, were widely employed in teak management in India, Burma and Thailand.

Coppice with Standards.

The coppice with standards system has been applied to the teak pole forests of Mysore and Kerala where the tree does not attain large size (Fig. 14). The rotation varies generally from 30 to 60 years; in rare instances it is 80 years. It differs from the more recent "Coppice with Reserves" system, in retaining fewer and more carefully selected trees as standards. The number of standards per acre and their diameter are generally fixed, the former being commonly 10 to 20 but sometimes up to 50. What is know as "modified clearfellings" in which all young growth below 12 inches has to be retained on gentler slopes and below 18 inches in girth on steeper slopes has been prescribed on the Ponna division reserves of Maharashtra. Recent working plans of Belgaum and North Kanara (Mysore) generally prescribe that coppice regeneration should be supplemented by artificial *rab* (small patch) planting of teak (Fig. 15). Thinnings for the coppice crops are prescribed in some instances, the first and second thinnings being in the 6th and 15th years, 15th and 30th years or 11th and 31st years respectively. A preliminary coppice cleaning some years before the first thinning has also been prescribed in one instance. (Fig. 16).

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In recent years, saleable non-teak is first cut, then teak, followed by improvement fellings, and this is believed to be an improvement on past methods.

Utilizing gregarious flowering of bamboo. Accompanying a gregarious bamboo flowering, overhead non-teak trees are removed resulting in stocked patches of teak.

Teak has been harvested in Thailand for over a hundred years without much systematized management. Demonstration forests, the first with an area of close to 500 acres, have been organized. A rotation of 120 years is envisaged. Selection fellings are governed by exploitable size and a felling cycle of 30 years. Five 30 cm. girth (6.25 in. diameter) classes are recognized, the largest class being 200 plus cm. gbh. (25.45 in. dbh). Trees under 100 cm. gbh. (12.7 in. dbh) are not felled; and fellings are more conservative on better quality sites and restricted to 85 percent of the exploitable volume. The approximate average volume extracted annually from 1956 through 1966 has been estimated at 2.67 million cubic feet (Kaufman, 1968).

Elephants are employed for dragging timber from felling areas and lotting in timber depots. Trucks do the rest of the hauling.

Coppice Systems

Because teak sprouts prolifically, early silvicultural systems depended largely on coppicing for regeneration. In the past, coppice systems, variously modified to suit local situations, were widely employed in teak management in India, Burma and Thailand.

Coppice with Standards.

The coppice with standards system has been applied to the teak pole forests of Mysore and Kerala where the tree does not attain large size (Fig. 14). The rotation varies generally from 30 to 60 years; in rare instances it is 80 years. It differs from the more recent "Coppice with Reserves" system, in retaining fewer and more carefully selected trees as standards. The number of standards per acre and their diameter are generally fixed, the former being commonly 10 to 20 but sometimes up to 50. What is know as "modified clearfellings" in which all young growth below 12 inches has to be retained on gentler slopes and below 18 inches in girth on steeper slopes has been prescribed on the Ponna division reserves of Maharashtra. Recent working plans of Belgaum and North Kanara (Mysore) generally prescribe that coppice regeneration should be supplemented by artificial *rab* (small patch) planting of teak (Fig. 15). Thinnings for the coppice crops are prescribed in some instances, the first and second thinnings being in the 6th and 15th years, 15th and 30th years or 11th and 31st years respectively. A preliminary coppice cleaning some years before the first thinning has also been prescribed in one instance. (Fig. 16).

Figure 14. *Teak "coppice with standards" system Madhya Pradesh: Ten standards per acre 18 to 26 inches in girth, coppice is coming up well in between the standards. (Forest boundary pillar in the right foreground).*

Photo, J. N. Sen Gupta

Figure 15. *Introduction of teak in "rab" patches, Colaba District, Maharashtra. This method is used to supplement coppice regeneration seen behind the "rab" patch. The method is also practiced in parts of North Kanara District, Mysore.*

The tending operations described above fall thus under two categories: (1) those for improving the old crop by thinning and cleaning, and (2) those which help bring in a young crop by weeding. cleaning and cutting back of suppressed teak.

Seedling Coppice Regeneration System.

In many forests of Burma there is a "fair to good" regeneration of teak on the ground. On clearing the overwood for taungya and burning the slash, this regeneration shoots up vigorously, since fire favors teak more than its associate species. Subsequent tending and thinning operations done to favor teak result in a forest of almost pure teak. The system is cheap, and similar to the "conversion to uniform" practiced in Madhya Pradesh, India.

Modified Uniform System

A system in use since 1930 in parts of Madhya Pradesh converts natural forest to uniform stands through clearfelling by stages to induce natural regeneration, with supplemental planting as needed. These measures, together with light burning, can produce nearly pure crops of coppice teak.

In these areas, the original forest consists generally of teak, *Terminalia tomentosa, Pterocarpus marsupium, Anogeissus latifolia, Adina cordifolia, Ougeinia dalbergioides, Bombax malabaricum* and others. *Dendrocalamus strictus* bamboo is nearly always present. There is often abundant advance growth of teak and its associates, and the clearfelling therefore involves considerable sacrifice of valuable growing stock of the younger age groups. The rationale of this operation has been questioned because of this. The remarkable fact is that in Madhya Pradesh and parts of Maharashtra, on clearfelling of the natural forest, teak tends to displace the regeneration of its associate trees, so that the resulting crop contains a much higher proportion of teak than its mother crop (Fig. 17). However, invariably, there are patches of natural forest in which teak reproduction is deficient and so a full stocking cannot always be obtained by clearfelling alone. In such places natural reproduction is supplemented by plantations of teak and other valuable species (Fig. 18). Sixty to 80-year rotations have been fixed by some working plans for these areas.

The conversion to uniform depends almost entirely on the preexistence of advance growth and regeneration of teak at the time of the main felling. Where young teak is absent, clearfelling and concentrated artificial regeneration is the only alternative because it has not been possible to induce adequate natural regeneration by other means.

Diffuse planting is suitable for bamboo forests in which a gregarious seeding is in sight and if practiced about 5 years ahead of the seeding, a valuable teak crop could be held in reserve under the bamboo which would automatically get released and hold the ground against bamboo reproduction that follows each flowering.

Recent working plans prescribed treatments of a composite kind, which combines two or three of the above methods; a recent Kanara working plan has prescribed a system of jardinage with improvement fellings, selection fellings and clearfellings in a single main felling operation. In 40 years, each portion of the felling series is exploited twice, once for both teak and other woods, the next time for non-teak woods only, the latter being followed by "diffuse planting" of teak stumps in the canopy openings.

At the end of the rotation one half the area will have planted stock of teak, the rest will have useful species best suited for the locality coming in by natural reproduction.

Clearfelling with Artificial Regeneration.

In this widely used system, clearfelling is followed by concentrated artificial regeneration in the form of stump plantings or less commonly, seedlings. The forest is cleared of all merchantable material except the slash required for a good burn which is burned shortly before the planting season. The area is planted up with teak stumps (occasionally seed is sown) early in the monsoon. Where there is demand for cultivable land, the area is leased out for a year or more for taungya intercultivation.

Treatment of Bamboos for Teak Regeneration

In parts of India and Burma, management of teak is intimately connected with the habits of the bamboos associated with it.

When bamboo is not in flower it is possible, especially in Burma, to procure natural regeneration of teak by felling the bamboo, clearing the forest undergrowth for some distance round teak seed-bearers, burning the material, cutting back the teak seedlings which are injured by fire, and weeding and tending for two to three years and subsequently keeping the teak regeneration clear of overhead bamboo and other growth. If burning is not adequate, there is every likelihood of failure of this operation. Troup (1921, p. 757) has described an instance in Burma of a plot of heavily worked *Bambusa polymorpha* with much slash which was accidently burned; here teak regeneration emerged which was so profuse as to look like a fully stocked nursery bed.

Annual or periodic cutting of bamboos is necessary until teak plants are free from danger of suppression, and this work is often costly. The vigor with which bamboos resprout is phenomenal, and if burning has been inadequate nothing short of a laborious, annual cutting back of the bamboo for four to five years may save the teak

(Fig. 19). In higher rainfall areas where *Bambusa arundinacea* is the associate bamboo teak may need help against the bamboo until it is perhaps 25 years old. Under a closed canopy the need for such late clearing is much reduced.

Figure 19. *In bamboo forests the bamboos resprout with phenomenal vigor in teak plantations; unless the bamboos are repeatedly cut back, teak may disappear.*

The importance, for the natural regeneration of teak, of a gregarous bamboo flowering lies in the fact that the entire bamboo crop dies and is consumed by fire. This admits light and warmth to the soil and often stimulates natural reproduction of teak. In Burma, instances are on record where satisfactory teak reproduction occurred only after such flowering.In 1907-08, in Upper Burma, after the bamboo *Cephalostachyum pergracile* flowered and the resulting bamboo slash was allowed to burn, regeneration of teak was quite satisfactory (Troup, 1921, p. 758).

Experience in India with *Dendrocalamus strictus* was somewhat different. In Bhadravati division, Mysore, after the gregarious flowering of the bamboo in 1933-35, teak failed to reproduce adequately in the canopy openings caused by the death of bamboo because the fierce fires which followed the flowering destroyed most of the teak seeds as well as the few seedlings which had appeared between the death of the bamboo and the time of the burn. Teak saplings established before the flowering were much stimulated. Where the fire was not so severe, patches of young teak appeared. Thus, the stage of advance growth of teak at the time of a flowering is an important factor in teak regeneration. While natural reproduction alone cannot guarantee complete restocking of bamboo flowered areas, such flowering creates good opportunities for restocking the forest with teak provided staff and labor are adequate for the necessary supplemental planting and tending over the flowered areas.

The following measures would be useful for restocking flowered bamboo (*D. strictus*) areas with teak:

(1) The forest staff should be on the lookout for an impending bamboo flowering, an important indication of which is that, in the year preceding a flowering, the annual (new) culms generally do not appear. Flowering starts generally at one epicenter and sweeps in ever widening waves over the whole area in 3 to 4 or more years.

(2) Adequate planting stock of teak should be prepared for the planting, situated as close to the planting site as possible.

(3) Flowered areas should be protected from fire until the bamboos are dry enough to burn properly, which will be the hot season following the season in which bamboo seeds are shed, then deliberately burned to destroy as much bamboo seed as possible.

(4) Where natural regeneration is inadequate, teak should be stump-planted at 6x6 feet spacing early in the monsoon following the burning.

(5) Adequate weeding and tending should be done to keep down bamboo regeneration which invariably comes up. The object should be to get the teak plants up as quickly as possible to develop a closed canopy which alone could keep down the bamboo regeneration.

Planting teak stumps a couple of years in advance of impending bamboo flowering--advance planting under the existing forest canopy, tried with some success in parts of Maharashtra and Madhya Pradesh, is well worth greater attention. To reduce chances of failures of stray stumps under the mother canopy, it is decidedly advantageous to plant stumps in groups of half a dozen to a dozen at each spot, but so closely spaced that even if the majority should die, the few that survive may shoot up to form a close canopy.

The method of management in East Pakistan is to clearfell natural forest, utilize merchantable timber, burn the slash and plant up the area mostly with teak. From the economic point of view, conversion of mixed semi-evergreen and evergreen forests of low value to pure stands of a highly marketable species like teak may be desirable. But the hazards of clearfelling forests in watershed areas, including the risks of soil erosion, and of laterization of the soil under pure teak, need careful examination. The wisdom of putting the soil under a pure teak crop has been questioned (Ghani, 1957, p. 32-5).

In Java, the financial period of return of teak is about 60 years but, in a country which cannot supply all of its own timber needs, the period chosen should provide the maximum utilizable production. A period of 80-100 years has therefore been adopted in practice.

As in Burma and India the teak forests of Java were first managed by selection fellings and natural regeneration. Later, and until about 1800, heavy fellings were made, seed trees were left, slash was burned, and seed was sown broadcast or with a planting stick. Management then shifted to clearfelling with artificial regeneration by taungya, first by paid labor, later by piece wages and agriculture.

Since 1907 pure teak planted by the taungya method has been interplanted with *Leucaena glauce.*

Maharashtra, frosts occuring earlier than January do less damage than those occurring after the 10th of January. Damage to standing crop probably occurred between January and February 10th, during the previous, severe frost years 1875, 1899, 1905, 1929, 1934, and 1935, i.e. 6 times in 63 years. Frost damage occurred only in years when temperatures below 40°F. lasted over 3 consecutive days.[99,100]

In Argentina (South America), young teak in its first year is reportedly sensitive to frost and dies back almost to the base of the stem but has the ability to resprout.[101]

Wind.

Wind damage to teak is not normally serious but occasionally, it can prove disastrous to plantations. In October, 1938, a cyclone passed over the old plantations of Puri, Orissa, damaging them so badly that they presented a tragic sight and "thirty years of work was ruined in a night." A hailstorm occurred early in October 1936, resulting in serious damage to forests and teak plantations.[102] Similar heavy damage has been reported from Yeotamal and Chanda of Maharashtra where teak trees were uprooted and broken by violent storms in 1934. In Amaraoti, in 1937, very heavy damage was done in August by a severe storm which broke 300 trees over an area of 91 acres.[103] In Andamans, teak saplings were swayed and bent by wind and their roots also loosened.[104]

In Tamil Nadu, Kerala, Mysore and other places, heavy winds occasionally bend and break teak stems. In Chittagong (East Pakistan) cyclones often damage teak plantations which are shallow rooted owing to the high water table. Tree belts of deep rooted indigenous species have been suggested as a remedy.

In Honduras, wind occasionally causes some damage, especially in the 6-year old, 6x6 ft. spaced stands, after a pruning, by bending over a few plants (Shubert, 1959).

Floods and Drought.

In general, teak can withstand short periods of flooding without serious damage, but nursery plants generally are destroyed if flooded.

Teak is sensitive to severe drought. It often recovers well after injury. Drought resulting from a prolonged break in the southwest monsoon often hampers planting operations. Stump-planting of teak

[99] Indian Forest, Jan. 1939.

[100] Forest Admin. Rep. Central Provinces, 1937.

[101] Letter, Feb. 4, 1970, from Director, Servicio Nacional Forestal, Buenos Aires.

[102] Silvicult. Res. Rep., Bihar and Orissa, 1942-43.

[103] Forest Admin. Rep. Central Provinces, 1937.

[104] Forest Admin. Rep. Andamans, 1916-17.

is an important palliative. Young regeneration from seedlings or pole coppice often suffer severely from drought also.

In the hot weather of 1921, owing to failure of the monsoons in 1920, over 50,000 trees, one foot and over in girth died in the Markhanda and Wainganga felling series of Madhya Pradesh.[105] Examples of striking recovery of the trees which have suffered from drought come from Maharashtra. In 1924, a complete set of new branches was produced in place of those which had died back.

In Trinidad, exceptionally severe dry weather in 1963 caused premature yellowing of teak leaves.

Insects

Defoliators.

A large number of insects defoliate teak; some 25 to 30 species having been found in Nilambur (Kerala) alone, but the larvae of *Hybloea puera* Cram. and *Hapalia machaeralis* Walker, are the two responsible for the epidemics in India and Burma.

Defoliation occurs in almost all the states of India, and it is frequent and periodically severe in Orissa, Maharashtra, Tamil Nadu, Mysore, Coorg, and Kerala. In West Bengal, Bihar, Madhya Pradesh and some parts of Mysore it is not considered serious, and in Uttar Pradesh it is insignificant.[106]

Defoliation is probably more common, and more serious, in pure teak crops, especially if undergrowth is inadequate. Moderate crown dilution of teak with other species probably does not affect the intensity of defoliation to any appreciable extent.[107] According to Beeson (1934, P. 672), contiguous blocks of plantations are more likely to suffer from epidemic defoliations than those interrupted by strips of natural forest having good natural undergrowth which can harbor the parasites and predators of the defoliating insects.

The loss of increment in teak as a result of defoliation has been variously estimated. Mackenzie (1921) states that teak suffers a loss 1/12 of its annual increment. Beeson (1931) has estimated the loss at 8.2 percent of the annual increment. The loss has been estimated by Champion 1934 at 60 to 70 percent of the basal area increment. Defoliation by *Hapalia machaeralis* causes greater loss of increment on teak as it directly retards girth increment. Another kind of damage to trees attributed to defoliation is the loss of timber quality by forking, death of the leading shoot, formation of epicormic branches and the like. In Ceylon, defoliator and skeletonizer attacks have been noticed in some plantations.[108] In East Pakistan,

[105] Forest Res. in India, 1921-22, p. 24.
[106] Silviculturist, Uttar Pradesh, letter No. 925 c/1A-3(0) 13th April 1953.
[107] Indian Forest Rec. N. S. 5 (1) Silviculture, p. 35.
[108] Letter Dec. 14, 1969, Conservator of Forests, Colombo 2, Ceylon.

defoliation of teak is of local occurrence, and a suggested remedy is to maintain belts of evergreen species in teak plantations. In Java, among the injurious insects mentioned are *Pyrausta machaeralis* (Syn, *Hapalia machearalis*) and *Syleborus destruens.*

Hybloea puera. The caterpillars of this moth consume the whole leaf including the midrib. Climatic conditions, particularly temperature and, to a less extent, the quality of food, determine the length of its life cycle which varies from 17 to 38 days in south India and from 16 to 42 days in north India. A very young larva must have soft, tender leaf tissue to feed upon and this may account for the fact that early sprouting teak trees often escape defoliation. At Nilambur, the defoliator is abundant form April to early June, with sometimes a second phase in August-September, in Coorg in May-June and again in October; in Maharashtra the peak attack is in July, in Madhya Pradesh in July-August, in Dehra Dun attack is in July and again in September. Intensity and frequency of defoliation varies with the age of the crop, being high from 1 to 10 years, maximum from 21-30 years, falling rapidly thereafter. Frequency of defoliation is highest in the age span of 11 to 45 years. The general falling-off of intensity from age 30, which becomes still more marked above age 50, is perhaps due to increased incidence of natural enemies of the defoliator.

Hapalia machaeralis. This moth is called the "skeletonizer," because its larvae eat the parenchyma but leave the veins intact. Quickest development takes place in March-May and slowest in November-December. Length of life cycle is 35 to 38 days in Mysore, 24 to 26 days in Madhya Pradesh, 23 to 25 days in Uttar Pradesh, and from 15 days to over 6 months at Dehra Dun (Beeson, 1941).

The chief alternative food plants of *H. machaeralis* in India are *Callicarpa arborea* and *C. macrophylla.* Unlike *Hybloea puera,* larva of *Hapalia machaeralis* can survive throughout life on an exclusive diet of tough, brittle leaves. This accounts for the abundance of the latter at the end of the growing season. Even the leader and lateral shoots of teak are often grooved and hollowed out.

The seasonal abundance of *H. machaeralis* is determined chiefly by climate. In Nilambur (Kerala), the insect is abundant in April-May and in November, in Coorg in October-January, in Kanara districts (Mysore) in May and early June and in September, in Central India in May-June, if rainfall is exceptionally heavy, otherwise from September onwards, in Dehra Dun in October - November. The destruction of foliage during the period autumn-spring seems to have little effect on the current-annual increment of the year, though the increment of the following year may be affected, but no precise studies have been made in this connection.

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Control of Defoliation. Damage from defoliation has not been considered so very serious as to justify the expense of direct control measures like aerial dusting, or spraying. The life cycles of the defoliaters are also short and follow each other.so rapidly that it is not practicable to organize such remedial measures.

Measures for the control of defoliators may be based on two distinct objectives: (1) to reduce frequency if not to prevent extensive epidemics, (2) to restrict damage when the complete stripping stage has been reached. Under the present conditions of forest management there is little hope of dealing with defoliators when they have reached epidemic stage. Attention has therefore been rightly given to the "policy of prevention." There are three factors which mainly control abundance of the defoliators: (1) their food supply, (2) their parasites and predators, and (3) climate. Control efforts may benefit from favorable climatic events when they occur, but main dependence must be on limiting food supply and fostering parasites and predators.

Food Supplies. Unless alternate plants are available, larvae of both the important defoliators starve during the period when teak is leafless. One approach to control is to eliminate understory plants which serve as alternate hosts to these insects. Beeson (1938) considers the following plants are undesirable in teak plantations because they provide alternative food for defoliaters: *Callicarpa arborea, Calanata, Gmelina arborea, Macarange roxburghii, Premna latifolia, Vitex negundo, V. penduncularis* and *Lantana camara.*

Since the newly hatched larvae of *H. puera* cannot survive on tough mature teak leaves, an early closed canopy is advantageous, because it reduces young epicormic and coppice foliage. Heavy defoliation which stimulates further growth of epicormics often facilitates further defoliation and is therefore not desirable. On the other hand, the removal of the older leaves by *H. machaeralis*, late in the season may lengthen the period of no food and thus be beneficial.

Among the palliative measures tried is the leaving of unfelled strips of natural forest between teak plantations; this was tried in Travancore and proved to be of little use. According to Champion (1934) defoliation of teak reduces growth and also deteriorates timber quality. Observations by Kadambi in the Nilambur teak plantations include: (1) intensity of defoliation among teak trees increases with distance from the bank of a stream, (2) solitary trees escape defoliation, although trees all around them have been completely stripped (Fig. 20); such trees probably are inherently immune, and might affort a basis for development of teak strains immune to defoliators. Seed origin seems to have no direct influence on defoliation, forking, or gall formation, since all origins are equally affected as borne out from observation made in the All-India seed origin plots of Coorg.

Figure 20. *Solitary unstripped teak tree standing amidst others completely stripped by the defoliating insect* Hybloea Puera. *Such trees are probably inherently resistant to defoliation. Nilambur Plantation, Kerala.*

Climate.

Prolonged, rainless hot weather favors defoliation but early intermittent rainfall before the monsoon destroys the defoliators. The activities of moths of both species and their oviposition are checked by rainfall.

Natural Enemies.

In addition to climatic factors there is an intricate system of controlling agencies against these caterpillars. The predaceous enemies of the defoliators include several ground beetles, several kinds of ants, bugs, three species of *Mantidae*, one of *Mantispinae,* three of *Chryropinae,* a species of *Syrphidae* and a large number of spiders, lizards and birds.

Teak defoliators are only part of the food supply of the predators, and their life histories are therefore independent of them. In spite of the spectacular appearance of crows, mynahs, etc. in defoliated plantations, the assistance obtainable by artificially increasing the abundance of predators is not likely to be high, except perhaps in the case of ants.

The parasites of the defoliators, on the other hand, which include chalcids, branconids, ichneumonids, tachinids, etc., are more closely associated with the life cycles of their hosts; when the latter increase the parasites also increase. The maintenance of a natural supply of parasites is within the limitations of practical silviculture. [109]

We have thus to rely on biological control for a permanent and inexpensive relief against teak defoliation. Most promising is the maintenance of natural undergrowth composed of plant species proved by investigation as useful for biological control of the pests.

Beeson (1938) has classified the species in the undergrowth according to their probable value in supporting the enemies of the two teak defoliators. It may be possible to increase efficiency of the undergrowth in defoliator control by selecting the useful kinds of plants and eliminating the neutral and harmful ones.

The following are the most useful plants in defoliator control, because they support insects which are parasites on both the major teak defoliators, *Hapalia machaeralis* and *Hybloea puera: Achyranthes aspera, Boerhavia sp., Helicteres isora, Holarrhaena antidysentrica, Xylia sylocarpa, Morus alba* and *Ricinus communis.*

Beeson has enumerated 18 plants which help in the control of *Hybloea puera* and 46 in the control of *Hapalis machaeralis,* suggesting that the natural control of *H. puera* by auxiliary parasites is less extensive than that of *H. machaeralis.* For the former, the most important auxiliary plant is *Holarrhaena antidysentrica* which supports the alternative host of *Sturmia inconspicuella,* often the most abundant parasite on *H. puera.*

Gall Insects. An undescribed species of *Itonididae* attacks new shoots of teak in plantations and natural forest and causes the formation of a globular, multilocular gall which envelops the stem. These galls may attain sizes up to 2½ inches in diameter. As the shoot grows the gall develops and becomes woody. This pest is specially abundant in teak growing localities on shallow, poor soils where the rate of growth is low.

Gall insect damage has been reported from central and southern India, and especially Mahya Pradesh, Coorg and other parts of Mysore, and parts of Tamil Nadu and Kerala. It is worse in the drier parts of the teak zone of Mysore, Andhra Pradesh and Madhya Pradesh than elsewhere. At Ramanapenta, which is about 2,500 ft. above sea level, a 15-acre plantation of 1937 suffered so heavily that some trees were killed outright.

109 Indian Forest, 54 (4).

It has been suggested that susceptibility to gall attack is an inherited or racial phenomenon; whether low rainfall or indifferent soil conditions are alone responsible for it, it is not possible to say. Teak trees do not normally die of this defect, though gall could become an accessory to death when the tree was already moribund from other causes.[110]

Other Insects.

The longicorm teak canker grub *Dihammus cervinus* emerges in epidemic form in young plantations (2 to 7 years old) of West Bengal, Assam, Bihar and Uttar Pradesh, but is unknown in South India. It is probably most serious in pure crops. Teak, however, generally grows out of the damage, and no serious injury is caused.

Damage to young teak by the larvae of *Hypophassus malabaricus* occurrs sporadically in South India (Nilambur) and parts of Maharashtra, but this seems to have no permanent effect on the plants. In Pakistan, *Dihammus cervinus* attacks unhealthy trees, the suggested remedy being to avoid growing teak on poor, shallow soils.

The beehole borer of teak which is the larva of the cossid *Duomitus ceramicus* Walker, and causes a loss of 10 to 15 percent of the total quantity of teak in Burma, rarely, if ever, occurs in India. The larvae cause large holes in the timber, erroneously called "bee holes", as well as branching and loss of bole form in the tree. In Malaysia, the stem borer *Endoclita gmelinae* is potentially harmful and difficult to control. The pest spends part of its life cycle in the undergrowth of eupatorium.[111]

In Thailand, two borers *Duomitus ceramicus* (Syn. *Xyleutes ceramicus* Walker) which bores the trunk, and *Zeuzera signifer* Walker which bores the twigs, have caused serious damage. *Phassus signifer* Walker, also a stem borer, is less damaging. *Parausta* (Syn. *Hapalia*) *machaeralis*, the common leaf skeletoniser, is also present. The stem borers have been controlled by spraying the fungus *Beauveria bassina* Vuillemin, on the boles and into the bore holes (Kaufman, 1968).

In Honduras, shot hole borers belonging to the family Scolytidae have occasionally killed teak trees (T. H. Schubert, 1959).

Young poles in Kanara North divison, Mysore are attacked by a stem borer, probably *Cossus cadambae* Moore.[112] Attacked stems are removed during the thinnings. The recommended method of minimizing damage in plantations is to thin early and heavily. In Travancore, Kerala (Troup, 1921, p. 715) the borer *Cossus cadambae*

110 Forestry Admin. Rep. Central Provinces, 1935.

111 Letter No. J. H. 16/54 (15), 5th Dec. 1969, Director of Forestry, West Malaysia.

112 Silvicult Res. Rep., Bombay, 1949-50.

causes damage to 2-year old teak in plantations by boring through the stem. The remedy lies in cutting back the stems. Woodpeckers are among the most important natural enemies of the borer grub.

Termites often do damage in teak nurseries; turning over the topsoil and adding oil emulsion has been found useful against them. In Zambia, E. Arica, termite attack, which was at first severe, was controlled by the application of aldrin to each plot prior to sowing.

In Trinidad (West Indies), the parasol ant (*Atta* sp.) which has appeared, has been controlled by aldrin and chloradane. In Panama, leaf cutting ants cause some damage at the establishment stage.

Cockchafers are another pest in teak nurseries, and removal of all larvae by hand to a depth of 1 to 1½ ft. while preparing nursery soil is recommended. Grasshoppers and locusts occasionally do serious local damage in Tamil Nadu, Kerala and Coorg, Mysore in young plantations during the first two years.

Plant Parasites

Mistletoe.

Teak, in common with 110 other tree and shrub species, suffers from attacks of a mistletoe, *Loranthus longiflorus* Desf. Var. *falcata.* The attack is considered a serious problem in the teak plantations of Maharashtra, but in Tamil Nadu, Kerala, and south Mysore damage is minor, though regular eradication measures are taken. Slight attack is reported from West Bengal, Bihar, and Orissa. Control measures consist in systematic lopping of the infected branches and removal of heavily infected trees in thinning. Loranthus is capable of doing serious injury, especially in pure crops of teak. Mixtures of susceptible species like *Gmelina arborea* and *Terminalia tomentosa* might seriously increase the incidence of this pest.

Loranthus occurs under very widely varied conditions of site, aspect, slope and soil and is not necessarily confined to poor localities. Poor site helps indirectly to increase the attack because the trees here are ill grown, and are generally scattered, thereby allowing more light and space for the loranthus to grow. This is the main reason for its preponderance along roads and other open places.

Pure teak plantations, especially from sapling to pole stages, become very common victims to loranthus. Birds are the vectors of loranthus infection.

Control methods suggested are:

(1) Cutting down of infected branches, a long established method.
(2) Selection of hardy races of teak for plantation purposes.
(3) Injecting chemicals which are selective phytocides into the attacked trees, a recent method that needs trial (Kadambi, 1954).

Lopping should be done before the end of December when the fruits of loranthus begin to ripen. The branches should be cut about a foot below the point of attack, and the loppings burned. It is of no use stripping loranthus from the branches, as the parasite remains lodged in the tissue of the host and regrowth starts from it. It is best not to use teak seed from loranthus infected trees.

Phenological information on loranthus from Tamil Nadu and Kerala indicates that there are two main flowering and fruiting seasons — one between November and March.

In Nilambur, the lopping of branches infected by loranthus was started in 1867 when the pest was first noticed. This operation is now prescribed for the year in which thinnings are done. In Mysore the parasite is found in the old teak plantations of North Kanara, Chikamangalur, Shimoga and Mysore districts and is generally removed during thinnings.

In Trinidad, three species of mistletoe *Phthirusa adunca* Maguire, *Phoradendron piperoides* H. B. and K. and *Viscum* sp. infest and kill teak trees. *Phthirusa* is commoner than *Phorandendron.*

Mistletoe has been controlled in Trinidad by lopping off infested branches, isolating new plantations from old ones, removing all infected trees within ¼ mile of the plantations, and planned layout so that the outer edge of the teak plantation is not more than 8 years old (Lamb, 1957). Experiments at the Forest Research Institute, Dehra Dun, on the control of loranthus by injecting affected host trees with a hormone weedicide and blue vitriol, indicate that *Loranthus pulverulenthus*, a parasite on *Dalbergia sissoo*, can be controlled by this method. The method is probably also applicable to teak (Kadambi 1954).

Fungi and Bacteria.

A rust, *Uredo tectonae* Roxb. is found widely distributed where teak is planted or natural. It is sometimes severe in nurseries, and retards the growth of young teak by premature defoliation. The uredo are numerous and almost plaster the lower surface of the leaves in dry localities of the Mysore plateau, round about Bangalore.[113]

K. D. Bagchee has described a fungus disease on teak at New Forest and at Gorakhpur (Uttar Pradesh) caused by the fungus *Hypomyces haematococus*, Berk. et. Br. The fungus, which attacks teak stems in underthinned or otherwise unhealthy plantations, is sometimes fatal, though frequently the tree forms a callus and heals itself. The symptoms noticed were: (1) the trees were drying up from top downwards, (2) their leaves became yellow and started shedding in September. The trees also developed extensive scars at various

113 Current Science, 1949.

heights from 6 to 12 ft. above the ground. Gum and tannin exuded from the affected parts which, on drying, showed both vertical and transverse cracks, and the bark peeled off with a blunt knife. Callus growth on the affected parts sometimes stopped the spread of infection.[114]

From Puri (Orissa) a lethal fungal attack on the cambial layer of teak trees has been reported. The fungus has not been identified.[115]

In Tirunalvely cum Ramnad division of Tamil Nadu, a fungus was found killing young planted teak in patches. In teak nurseries with congested seedlings, an unidentified fungus with white underground hyphae has also been noticed.[116] An unknown fungus causes hollow-heart in frost affected trees.

In West Malaysia an attack of bacterial wilt caused by *Pseudomonas* spp. occurred in 1959 in Jeniang Kedah, and in 1961 at Mata Ayer nursery. Both attacks were controlled by di-hydrostreptomycin and formaldehyde.

In Java, the fungus *Corticium salmonicolor* B. et Br., causes heartrot (Altona, 1923).

In Nigeria, *Fomes lignosus* has been responsible for root rot and death of 2 percent of teak plants in plantations (Lamb, 1968). *Rigidoporus lignosus* and *Armillarea mellea* also cause group deaths.[117]

In Tanzania (Africa), the fungi *Helicobasidium compactum* (Purple root rot) and *Armillarea mellea* have been notice on teak.[118]

In Honduras (Central America) a fungus of the genus *Polyporus* occasionally destroys the root systems of teak trees resulting in their uprootal.

Mammals

In parts of Central India domestic animals trample and destroy teak regeneration which comes up during the years of grazing closure, and a second closure is not enough to resuscitate such damaged seedlings.[119]

Damage to teak by elephant, bison, rusa deer, axis deer, porcupines, pigs, monkey, hares, rats, etc., have been reported from various parts of India and Burma and by elephants and wild boars from West Malaysia. In Mysore and Burma, wild elephants break down and uproot seedlings and saplings in plantations, trample over

114 Indian Forester, 1947, p. 332.

115 Forest. Admin. Rep., Bihar and Orissa, 1933-34.

116 Working plan for Tinnavelly *cum* Ramnad Division, 1934-44.

117 Commun. G. 481/2/215 - Feb. 6, 1970; Dir. Forest Res., Nigeria.

118 Commun. Dec. 8, 1969; Dir. Nat. Resources, Dar-es-Salaam, Tanzania.

119 Tour notes, Chief Conserv. of Forest., Nagpur-Warclha Div. Central Provinces, 1925.

Rats cause damage, sometimes very serious, by nibbling. Many promising plantations are decimated by rat attacks in the cold season.[126] Laurie has reported a case of very bad rat damage in Coorg with early stump planting. Damage occurs here mostly in summer, from 15th April to 15th June, and stops as soon as the stumps start active growth.[127] Pocket gopher, a rodent, chews up roots of young plants up to the 3rd year. Damage by hare has been reported from Maharashtra which eat off the shoots at ground level but new sprouts emerge from the root collar. Of several preventive methods tried against hares and rats the most effective were:

Early burning of the plantation coupes, which scares rats and hares.

Stopping of clear weeding, as weeding attracts rats and hares.

126 Indian Forest, 1926, p. 132.

127 M. V. Laurie, Tour Notes, 1940.

GROWTH AND YIELD

In the early decades of teak management in India and Burma, interest in growth and yields centered mainly on trees of merchantable or near-merchantable sizes in natural forests. Only after 1920, when data became available from Nilambur and other early plantation areas, was there an adequate basis for development of yield tables. Most of the earlier efforts were applicable only to the local stands from which they were derived, or through regional site classes, to somewhat broader areas.

After World War I, a coordinated program of sampling to provide data for widely applicable tables, resulted in the India-Burma site classification and yield tables of 1940.

Incorporation of additional observations on permanent and temporary sample plots in India, and elimination of the data from Burma, provided the basis for the India Yield and Stand Tables of 1964, which have been in use in India since 1958. Yield tables for teak plantations in Java, compiled in 1932 by Dr. Wolff Von Wuelfing, were based on more complete data than most yield tables of that time.

Diameter And Height Growth

While the sizes estimated for various ages on specific sites in the India and India-Burma yield tables are the most reliable, many of the data from earlier studies are of interest, as they reflect growing conditions of specific localities. (Fig. 21).

Figure 21. *Teak plantation on riverine alluvium, Mysore District, Mysore; height 65½ feet; g.b.h. 6½ feet; age 28 years. Seed origin: Mysore.*

Plantations.

Uttar Pradesh. Data are available from a number of sample plot measurements on plantations in areas north of the Ganges in Uttar Pradesh, all of them far north of the native range of teak:

Location	Age Years	Diameter inches	Height feet	Source
Haldwani Division	8	5.7	52	Tour notes, Inspector General, March 1936
Haldwani Division	21	13.8	85	
Gorkhpur Division	11	8.6	40	E.C. Mobbs, unpublished
Gorkhpur Division	44	12.2	74	
Ramgarh, Gorkpur Div.	50	17.3	66	Bhola, 1928
Ramgarh, Gorkpur Div.	75	15.1	75	Kadambi, 1952 unpublished
Ramgarh, Gorkpur Div. sprout growth	20 (75)	12.7	74	Kadambi, 1952

The three records from Ramgarh relate to plantations established in 1877-78, parts of which were clear-felled in 1932 after severe frost damage; the final measurement, made in 1952 shows the size of 20-year-old sprouts (75-year-old root systems) from this felling.

Comparative development of teak and sal (*Shorea robusta*) in mixed taungya plantings in Gorkhpur Division is shown below:

		Teak		Sal		
	Age Years	Diameter inches	Height feet	Diameter inches	Height feet	Soil drainage
Pharenda Range	28	14.0	79	8.7	60	Excellent
Pharenda Range	30	14.0	88			
West Lehra Compartment	28		81		60[1]	Good
West Lehra Compartment	29		81		61[1]	Good
West Lehra Compartment	30		88		75[1]	Good
Nagna Block	20		35		43[2]	Poor
Nagna Block	20		33		46[2]	Poor
East Lehra Compartment	28		40		25[1]	Good

[1] Teak seedlings outgrowing sal.
[2] Teak seedlings less vigorous than sal.

Teak generally grows faster than sal where drainage is good, but sal outgrows teak on poorly drained sites. Examination of root systems showed that teak roots spread near the surface, while those of sal dive vertically into the soil.

Growth of teak in plantings in northern Uttar Pradesh (Tarai and Bhabar divisions), measured by Kadambi in 1952 was slower than that of Khair (*Aeacia Catechu*) and shisham (*Dalbergia sissoo*):

	Diameter, inches			Height., feet		
Age	Teak	Khair	Shisham	Teak	Khair	Shisham
26	7.6	7.9	10.1	52	55	65
27	8.8	10.7	11.3	55	57	65
29	10.4	11.3	11.8	60	63	71
31	7.9	10.2	11.6	49	61	65

East Pakistan. Homfray (1935) recorded average heights of plantation teak for Chittagong Hill tracts division; one plot averaged 11.8 inches in diameter and 96 feet in height (volume of 1517 cu. ft. per acre to an 8 inch top) in 21 years. Another averaged 23.5 inches in diameter and 122 ft. in height, with a volume of 4,267 cu. ft. of stem wood per acre in 61 years.[128]

A sample plot at Chitmorum,[129] in an old regular plantation showed the following measurements at age 31:

No of stems per acre	113
Mean dbh	11.5 in.
Mean height of crop	80 ft.
Timber over 1.5 ft. girth	2,798 cu. ft.
Smallwood	441 cu. ft
Total volume	3,239 cu. ft.

The following sample plot figures give the growth of teak at Kaptai:

Sample plot number	Age years	Average height feet	Trees per acre	Mean diameter inches	Timber volume per acre cubic feet
25	61	122	38	23.5	4,219
22	46	99	70	15.6	2,716
3	27	98	80	14.7	
2	21	96	74	11.8	1,204
2	16	84	128	9.2	627
5	15	82	100	9.1	534
11	14	72	137	8.7	492
7	6		278	4.1	
	11	61	199	6.5	174
12	5		376	3.8	
	10	73	135	7.8	281
5	12	66	221	6.5	147
11	9	57	276	6.2	72

Kaptai teak grows faster than Nilambur I quality teak and in general, carries a larger volume per acre throughout its life.

128 Indian Forester, 48 (11).
129 Indian Forester, 50 (4), p. 185.

Tamil Nadu. Average heights and diameters of teak, read from curves based on measurements in Mudumalai plantations (Nilgiris Division) are as follows:

Age	Diameter, inches	Height, feet
5	3.1	18
10	5.8	31
15	7.9	41
20	9.6	49
25	10.9	57
30	12.2	63
35	13.2	70

Kerala. Average breast height diameters for young plantation teak at two locations in Palghat Division are as follows:

Age	Walayar	Bolampatty
	-------Diameter, inches---------	
3		1.9
4		2.3
5	2.8	2.6
6	3.3	3.1
7	3.9	3.4
8	4.3	3.8
9	4.6	
10	4.9	

Natural Forest Teak

Considerable information is available on the growth rate of teak in natural forests, especially for several states in central and southern India.

Madhya Pradesh. Data for forests of Hoshangabad Division, Madhya Pradesh, were compiled by J. W. Best, under two local site quality classifications. Data summarizing measurements on over 4,000 felled trees are extracted below:

Age	Sites where teak grows to more than 50 feet in 40 years		Sites where teak grows to less than 50 feet in 40 years	
	Mean height, feet	Mean dbh, inches	Mean height, feet	Mean dbh, inches
5	14	2.2	11	0.9
10	21	4.1	18	1.9
20	33	6.6	26	3.5
30	43	9.4	32	5.4
40	50	11.6	36	6.9
50	56	14.2	40	8.5
60	60	15.7	44	10.1
70	62	17.0	47	11.0
80	62	17.6	48	12.0
90	62	17.6	49	12.3
100	62	17.6		

Data from the same forest division, compiled by Central Provinces quality classes, reflects somewhat different growth curves, as follows:

Age years	Height, feet		Dbh, inches		Standard stem timber volume (under bark) cu. ft.	
	C.P. Quality II-III	C.P. Quality IVa-IVb	C.P. Quality II-III	C.P. Quality IVa-IVb	C.P. Quality II-III	C.P. Quality IVa-IVb
10	12	9	1.5	1.2		
20	26	19	5.2	4.4		
30	35	25	8.2	6.8	(2.0)[1]	
40	41	30	10.8	8.7	7.5	2.5
50	46	34	12.8	10.3	12.5	5.0
60	51	38	14.3	11.3	17.5	7.5
70	(56)[1]	(42)	15.4	12.1	22.0	9.0
80			16.4	12.8	26.0	10.5
90			(17.3)	(13.4)	(29.5)	(12.0)

[1]Figures in parentheses are based on extrapolation of curves.

Diameters of natural forest teak from Bori (Madhya Pradesh), determined by analysis of 121 stumps, 20 inches or more in diameter, are compared with India-Burma and Java site quality values in the following tabulation:

Diameter, breast high over bark.

Age (years)	Bori stump analysis	India-Burma Teak Yield Table Qualities IV	India-Burma Teak Yield Table Qualities V	Java Yield Table Qualities[1] III-IV	Java Yield Table Qualities[1] II-III
	Inches				
10	2.2	3.7	2.6	4.1	3.3
20	4.4	5.5	3.8	6.5	5.0
30	6.6	6.8	4.8	8.6	6.5
40	8.7	8.0	5.6	10.5	7.9
50	10.7	9.3	6.4	12.2	9.1
60	12.6	11.1	7.4	13.8	10.2
70	14.0	13.2	8.6	15.2	11.3
80	16.0	16.6	10.0	16.5	12.3
90	17.5			17.7	13.2
100	18.8			18.9	14.2
110	(19.9)[2]			20.0	15.5

[1] In the Java tables, quality V is the best, quality I is poorest.
[2] Extrapolated from curves.

Diameter increment in Bori is at first slower than in India-Burma V quality, but exceeds it before age 20 and also exceeds India-Burma IV from age 40 to 70. Diameter growth of Bori teak starts slower than Java Quality II/III, but becomes faster, so that diameter at 100 years nearly equals that of Java Quality III/IV. The departure from the India-Burma curves is due to their rapid rise after 50 years owing probably to heavy thinnings.

Diameter increment of Bori teak is slow even for dominant trees (which are considerably openly stocked), and thus the age corresponding to exploitable diameter of say 20 inches will be somewhere in the neighborhood of 130 years.[130] The following table (Sagreiya, 1957) gives the rate of diameter growth determined from stump and stem analyses on teak in various divisions of Maharashtra and Madhya Pradesh:

Age years	Diameter breast high			
	Allapalli	Bori	Arvi	Deolapur
		Inches		
10	1.6		2.5	0.7
20	4.1		4.2	4.1
30	6.4		6.2	6.7
40	8.5	8.7	7.9	8.8
50	10.4	10.7		10.4
60	12.1	12.6		11.7
70	13.6	14.4		12.7
80	14.9	16.0		13.5
90	16.1	17.5		14.2
100	17.2	18.8		14.8
110	18.2	(19.9)[1]		
120	19.0	(21.0)		

[1]Figures in parentheses are based on extrapolation of curves.

Maharashtra. The following tabulation based on stem analysis of trees from Allapalli range, shows comparable diameter growth to about age 60, but considerably larger diameters for older trees:

Age (Years)	Dbh, inches[1]	Total Height, feet[2]
5	1.0	9
20	4.0	25
40	8.1	60
60	12.8	77
80	17.0	86
100	20.4	91
120	23.2	96

[1]Based on 7 trees.

[2]Based on 9 trees.

The following figures showing the rate of growth of teak in Nagpur-Wardha Division, Maharashtra, are based on stem analyses and on measurements taken in natural forest while stock mapping.[131] The investigation was not comprehensive but care was taken to select samples not influenced by extraneous disturbing factors:

[130] Silvicult. Res. Rep., Central Provinces, 1940-41, p. 21-28.

[131]Working Plan for the Nagpur-Wardha Division, Central Provinces, 1936-46, Pp. 25-26.

Age years	Diameter, breast high Slow Growth	Average Growth	Vigorous Growth	Height Under 40 feet quality Seedling	Coppice	40-50 ft. quality	Over 50 ft. quality
	Inches			feet			
5	2.1	2.4	2.7	8	13	13	18
10	3.2	3.6	2.8	14	21	21	28
15	4.1	5.4	4.3	18	27	27	28
20	4.3	6.7	5.8	18	27	27	35
25	5.4	7.4	7.0	22	30	36	40
30	5.4	7.4	7.0	26	33	36	45
30	6.7	7.8	8.2	29	35	39	48
35	7.4	8.0	9.1	31	37	42	51
40	7.9	8.2	9.8	34	38	44	54
45	8.0	8.3	10.5	35	38	46	55

Trap Zone

Metamorphic zone

Age Years	Diameter, breast high Average	Good	Height Feet
	Inches		
5	2.7	3.3	26.0
10	3.9	4.9	28.5
15	4.9	6.3	45.5
20	5.7	7.4	51.0
25	6.4	8.1	54.0
30	6.9	8.7	57.0
35	7.4	9.1	58.5
40	7.7	9.4	60.0
45	7.9	9.7	61.0

The above figures suggest the following:

The poorer and medium quality teak forests of the trap range mature in 45-50 years, and are generally incapable of producing stems of more than 3 feet in girth.

The better quality forests continue to put on girth and height increment for a least 45 years and, if properly tended, can produce stems 4 feet and over in girth.

Good teak in the metamorphic zone is capable of producing large timber, and could be grown on a longer rotation.

Tamil Nadu. The slower juvenile growth of natural forest teak, as compared with that of plantation teak, is illustrated by the data from stump analysis in Mudumalai Reserve, which follow: [132]

[132] Working plan for the Nilghiris Forest Division, Madras, 1941, Pp. 109-10.

Age, years	Diameter, 1 foot above ground, inches	Age, years	Diameter, 1 foot above ground, inches
10	3.2	80	17.6
20	5.4	90	18.9
30	7.9	100	20.1
40	10.4	110	21.1
50	12.6	120	22.3
60	14.5	130	23.3
70	16.4	140	23.9

Kerala. Diameter growth of teak in Walayar Valley Pole Working Circle, Palghat Division,[133] as determined by stump analysis is as follows:

Age, years	Diameter inside bark, inches	Age, years	Diameter inside bark, inches
5	2.6	35	12.2
10	4.0	40	13.6
15	5.6	45	14.7
20	7.2	50	15.5
25	9.0	55	16.0
30	10.6	60	16.2

Diameter growth of natural teak coppice, Walayar Valley, Palghat division,133 Kerala:

Age years	Dbh, inches	Age, years	Dbh, inches
6	2.8	10	3.5
7	3.0	11	3.7
8	3.2	12	3.8
9	3.3		

Teak Yield and Stand Tables.

Widely useful in the management of teak forests and plantations has been the consolidation of the results of decades of teak management into yield and stand tables. Incorporating, as they do, the concepts of measured site quality and the recorded results of thinnings, those tables serve in several ways to guide the practice of forest management and the application of silvicultural treatments.

Estimating rotations. By predicting trends and levels of wood production, as well as indications of product size (and therefore value), yield tables afford the basic information needed to select rotations to meet management objectives. By applying net value figures to the yield table, a set of money yield figures can be obtained

[133] Working plan of the Walayar, Bolampatty and Tagadam Valley, Palghat Division, Madras, 1937-46.

for the total crop at different ages, and these, when divided by the approximate ages, give the mean annual net value increment per acre.

Site quality. On the basis of the relationship of top height to age, five standard quality classes have been distinguished in the 1940 tables and four in the 1964 tables. Top height (height corresponding to average of 100 trees of largest diameter per acre) has been found to be practically independent of the density of the crop and the thinning treatment it has received, and the tables are therefore a fair guide to the site quality of an even-aged pure crop, irrespective of the treatment it has received in the past.

Yield regulation. When the site quality has been determined, the yield tables give an estimate of the stocking on the ground for a fully stocked crop and the yield which can be obtained from such a crop if treated similarly to past practices. The probable future yield of an abnormal crop can be roughly estimated with the help of the yield table by determining the existing basal area of the crop and comparing it with that in the yield table for the same age and quality, thereby obtaining a "stocking factor." The factor is then multiplied by the values given in the table to obtain the yield estimate.

A guide to thinning. The table is constructed for a 5-year thinning cycle. When using the figures for a longer thinning cycle, the main crop number of stems 5 years before the thinning date and the number of stems at C − 5 years (C − thinning cycle) after the thinning date is determined. If the crop is normal the difference between this value and the existing number of stems will give the number of stems which have to be removed. A crop which has been over thinned in respect of its age and quality in the past and where stems have a larger than normal mean diameter will be spaced out more widely than one which is in accordance with the yield table standards and *vice versa.* Such abnormalities are adjusted over two or more thinning cycles.

Standard of normality. The yield table, although not a perfect standard of normality, is a valuable guide for judging the relative condition of the crops on the ground as compared with this standard. The number of stems per acre for the main crop given in the table represents a condition that is in accordance with the ideas of thinning prevailing at the time of preparation of the tables.

Nilambur and Java Yield Tables.

The first yield table for Indian teak was compiled in 1921 by R. Bourne for the Nilambur teak plantations (Kerala) based on data from 76 temporary and a few permanent sample plots (Fig. 22). Though based on insufficient data, this was a fine piece of work. In 1932 Dr. Wolff Von Wuelfing compiled yield tables for Java

Figure 22. *Teak plantation of India I quality at Nilambur, Kerala. Height 112 feet; age 53 years.*

plantations based on more complete data, including sample plot work initiated in 1895, and representing crops which had received more systematic treatment than those at Nilambur. As they belong to a country with substantially different growth conditions, they have been of considerable interest to teak growers, but little used as a standard of reference in India. [134]

The Java yield tables were prepared, in substance by the method of Bruce (modified by Reineke). The top height of the stem at age 80 years is used as site index for determination of the quality classes. For classes I, I/II, V/VI and VI there are no actual measurements, the data having been found by extrapolation. Stands of V/VI and VI (Top qualities) will probably be very scarce, while those of classes I/II are found on soils which are unsuitable for teak.

India-Burma Yield and Stand Tables, 1940

Systematic sample plot work was started in India about 1917, and the first yield tables for India-Burma (Laurie and Sant Ram. 1940) compiled according to the standard Indian practice in 1937-39, were

[134] Indian Forest Bulletin 87, 1934.

the best obtainable at the time. They were based on measurements of 387 permanent sample plots over a period of about 25 years, and contain, therefore, a large volume of reliable data. The use of top height (that corresponding to the 100 largest diameters per acre) was continued as the best indication of site quality at known age. The tables are given for five site qualities based on 20 foot differences in top height at 80 years of age; a useful series of stand tables, spacement tables, and tables of normal growing stock on a 70- and 80-year rotations is included.

The height/age curves agree generally with those of Bourne and with Von Wuelfing's table from Java, except that Bourne's curves for low quality are lower at middle age by half a quality class.

Direct correlation of quality class and rainfall was not found, but quality class I may occur with less than 60 inches rainfall. It is interesting to note that the rotation of maximum net income is considerably longer than the rotation of maximum volume production per acre, and that under the existing thinning methods, the most paying rotation for III quality crops is well over 100 years.

India Yield and Stand Tables for Plantation Teak.

A substantial number of the sample plots on which the India-Burma Yield and Stand Tables were based has been laid out in inadequately thinned crops, and the growth trends of plantation teak as indicated by them were found unsatisfactory. Need arose also to exclude the sample plots from Burma and East Pakistan which made up the bulk of the plots on which those yield tables were based. Necessity was therefore felt for revising those tables.

The inadequacy of the residual sample plot data consequent on the elimination of the Burma-Pakistan plots was made up by measuring 20 temporary sample plots in Madhya Pradesh and Bombay.

Compliation of the new Yield and Stand Tables for Plantation Teak in India (Anon. 1964) was begun at the Forest Research Institute, Dehra Dun, in 1951 and completed in 1958. They are based on 617 measurements on 326 sample plots located in India. Selected values from these tables are presented in Table 5.

Systematic sample plot work was started in India about 1917, and the first yield tables for India-Burma (Laurie and Sant Ram, 1940) the best obtainable at the time. They were based on measurements of 387 permanent sample plots over a period of about 25 years, and contain, therefore, a large volume of reliable data. The use of top height (that corresponding to the 100 largest diameters per acre) was continued as the best indication of site quality at known age. The tables are given for five site qualities based on 20 foot differences in top height at 80 years of age; a useful series of stand tables, spacement tables, and tables of normal growing stock on a 70- and 80-year rotations is included.

The height/age curves agree generally with those of Bourne and with Von Wuelfing's table from Java, except that Bourne's curves for low quality are lower at middle age by half a quality class.

Direct correlation of quality class and rainfall was not found, but quality class I may occur with less than 60 inches rainfall. It is interesting to note that the rotation of maximum net income is considerably longer than the rotation of maximum volume production per acre, and that under the existing thinning methods, the most paying rotation for III quality crops is well over 100 years.

India Yield and Stand Tables for Plantation Teak.

A substantial number of the sample plots on which the India-Burma Yield and Stand Tables were based has been laid out in inadequately thinned crops, and the growth trends of plantation teak as indicated by them were found unsatisfactory. Need arose also to exclude the sample plots from Burma and East Pakistan which made up the bulk of the plots on which those yield tables were based. Necessity was therefore felt for revising those tables.

The inadequacy of the residual sample plot data consequent on the elimination of the Burma-Pakistan plots was made up by measuring 20 temporary sample plots in Madhya Pradesh and Bombay.

Compliation of the new Yield and Stand Tables for Plantation Teak in India (Anon. 1964) was begun at the Forest Research Institute, Dehra Dun, in 1951 and completed in 1958. They are based on 617 measurements on 326 sample plots located in India. Selected values from these tables are presented in Table 5.

Systematic sample plot work was started in India about 1917, and the first yield tables for India-Burma (Laurie and Sant Ram, 1940)

Table 5. Selected values, India Yield and Stand Tables for Plantation Teak, 1964.

Age (years)	Average Diameter (in.)	Average height (ft.)	Total basal area (sq. ft.) per acre	Number of trees per acre	Periodic (5-year) thinnings, timberland stem smallwood[2]	Accumulated Thinning Yield, stem timber and stem smallwood	Total Yield, stem timber	Total Yield, stem smallwood	Total Yield, stem timber and stem smallwood	Mean Annual Increment, stem timber and stem smallwood	Current Annual Increment, stem timber and stem smallwood
					Cubic feet per acre						
				Site Quality I (top height, 120-100 feet at age 50)							
5	3.4	34	34	539	300	300	0	810	810	162	-------
10	5.8	52	47	256	395	695	80	1,665	1,745	175	187
15	8.2	65	56	153	435	1,130	405	2,135	2,540	169	159
20	10.7	76	64	102	535	1,665	990	2,225	3,215	161	135
25	13.1	85	70	75	535	2,200	1,740	2,050	3,790	152	115
30	15.1	91	76	61	395	2,595	2,480	2,035	4,515	151	145
35	17.0	97	82	52	330	2,925	3,215	2,050	5,265	150	150
40	18.8	102	88	46	280	3,205	3,885	2,060	5,945	149	136
45	20.4	106	94	41	235	3,440	4,500	2,070	6,570	146	125
50	21.8	110	99	38	185	3,625	5,075	2,070	7,145	143	115
55	23.0	113	104	36	150	3,775	5,550	2,075	7,625	139	96
60	23.9	117	109	35	120	3,895	5,965	2,070	8,035	134	82
65	24.9	120	114	34	105	4,000	6,335	2,075	8,410	129	75
70	25.7	123	119	33	100	4,100	6,650	2,070	8,720	125	62
75	26.6	126	123	32	100	4,200	6,925	2,075	9,000	120	56
80	27.5	129	128	31	100	4,300	7,160	2,070	9,230	115	46

Table 5, continued

Age (years)	Average Diameter (in.)	Average height (ft.)	Total basal area (sq. ft.) per acre	Number of trees per acre	Periodic (5-year) thinnings, timberland stem smallwood[2]	Accumulated Thinning Yield, stem timber and stem smallwood	Total Yield, stem timber	Total Yield, stem smallwood	Total Yield, stem timber and stem smallwood	Mean Annual Increment, stem timber and stem smallwood	Current Annual Increment, stem timber and stem smallwood
					Cubic feet per acre						
					Site QualityII (top height 100-80 feet at age 50)						
5	3.0	26	32	652	260	260	0	630	630	126	
10	4.6	41	40	347	335	595	10	1,325	1,335	134	141
15	6.2	51	45	215	355	950	120	1,870	1,990	133	131
20	7.8	61	50	151	151	1,310	400	2,240	2,640	132	130
25	9.3	67	54	114	345	1,655	755	2,370	3,125	125	97
30	10.8	73	58	91	275	1,930	1,140	2,260	3,400	113	55
35	12.1	77	62	78	250	2,180	1,455	2,275	3,820	109	84
40	13.4	82	66	67	215	2,395	1,955	2,290	4,245	106	85
45	14.6	86	71	61	185	2,580	2,370	2,310	4,680	104	87
50	15.7	89	74	55	165	2,745	2,740	2,325	5,065	101	77
55	16.7	92	79	52	140	2,885	3,105	2,340	5,445	99	76
60	17.7	96	83	49	130	3,015	3,455	2,360	5,815	97	74
65	18.6	99	87	46	120	3,135	3,760	2,375	6,135	94	64
70	19.4	101	91	44	110	3,245	4,050	2,385	6,435	92	60
75	20.3	104	94	42	110	3,355	4,340	2,395	6,735	90	60
80	21.2	106	98	40	105	3,460	4,520	2,400	7,020	88	57

Table 5, continued

Age (years)	Average Diameter (in.)	Average height (ft.)	Total basal area (sq. ft.) per acre	Number of trees per acre	Periodic (5-year) thinnings, timberland stem smallwood[2]	Accumulated Thinning Yield, stem timber and stem smallwood	Total Yield, stem timber	Total Yield, stem smallwood	Total Yield, stem timber and stem smallwood	Mean Annual Increment, stem timber and stem smallwood	Current Annual Increment, stem timber and stem smallwood
				-----	-----	-----	-----	Cubic feet per acre	-----	-----	-----
				Site Quality III, (Top height 80-60 feet at age 50)							
5	2.5	18	30	880	195	195	0	435	435	87	----
10	3.7	30	36	476	210	405	0	905	905	91	94
15	4.9	38	39	298	215	620	30	1,300	1,330	89	85
20	5.8	45	41	223	200	820	90	1,620	1,710	86	76
25	6.7	50	42	172	190	1,010	160	1,850	2,010	80	60
30	7.5	55	44	143	170	1,180	250	2,040	2,290	76	56
35	8.2	58	46	125	145	1,325	345	2,160	2,505	72	43
40	9.0	62	49	111	135	1,460	475	2,255	2,730	68	45
45	9.7	65	52	101	125	1,585	640	2,305	2,945	65	43
50	10.4	68	55	93	125	1,710	845	2,305	3,150	63	41
55	11.1	71	58	86	125	1,835	1,070	2,305	3,375	61	45
60	11.8	73	61	81	130	1,965	1,330	2,295	3,625	60	50
65	12.5	76	64	75	130	2,095	1,605	2,300	3,905	60	56
70	13.1	78	66	70	125	2,220	1,880	2,310	4,190	60	57
75	13.8	80	69	66	120	2,340	2,175	2,325	4,500	60	62
80	14.5	82	72	63	115	2,455	2,490	2,335	4,825	60	65

Table 5, continued

Age (years)	Average Diameter (in.)	Average height (ft.)	Total basal area (sq. ft.) per acre	Number of trees per acre	Periodic (5-year) thinnings, timberland stem smallwood[2]	Accumulated Thinning Yield, stem timber and stem smallwood	Total Yield, stem timber	Total Yield, stem smallwood	Total Yield, stem timber and stem smallwood	Mean Annual Increment, stem timber and stem smallwood	Current Annual Increment, stem timber and stem smallwood
					Cubic feet per acre						
Site Quality IV (top height 60-40 feet at age 50).											
5	----	----	----	----	----	----	----	----	----	----	----
10	3.0	19	32	652	105	105	0	385	385	39	----
15	3.7	25	34	455	100	205	0	605	605	40	44
20	4.3	30	35	347	90	295	0	795	795	40	38
25	4.8	34	35	278	80	375	0	945	945	38	30
30	5.2	37	36	244	70	445	10	1,085	1,095	37	30
35	5.6	39	37	216	60	505	20	1,185	1,205	34	22
40	6.0	42	38	194	50	555	40	1,295	1,335	33	26
45	6.3	44	39	178	45	600	60	1,370	1,430	32	19
50	6.7	47	40	162	40	640	90	1,450	1,540	31	22
55	7.1	50	41	150	40	680	145	1,505	1,650	30	22
60	7.5	52	43	140	45	725	215	1,540	1,755	29	21
65	7.8	54	45	133	50	775	310	1,575	1,885	29	26
70	8.2	56	47	126	55	830	420	1,600	2,020	29	27
75	8.6	58	48	118	55	885	540	1,615	2,155	29	27
80	9.0	59	50	112	55	940	670	1,640	2,310	29	31

[1] Stem timber: volume, exclusive of bark, to 8 in d.o.b. top.

[2] Stem smallwood: volume, including bark, less than 8 in. and more than 2 in. d.o.b.

Comparisons Of Yield Tables

Table 6 compares top heights at different ages for the

Table 6. Top heights[1] of teak for comparable site qualites, by four yield tables

	50 ft at 80 years			70 ft. at 80 years				90 ft. at 80 years				110 ft. at 80 years				120 ft. at 80 years			
Age (years)	India-Burma (1940)[2] V-bottom[3]	India - 1964,[4] IV,bottom[3]	Java[5] I mean	Nilambur[6] III=bottom	India - Burma (1940) IV/V	India - 1964 III/IV	Java II mean	Nilambur II/III	India-Burma 1940 III/IV	India 1964 II/III	Java III mean	Nilambur I/II	India Burma (1940) II/III	India 1964 II mean[3]	Java IV mean[3]	Nilambur I top[3]	India-Burma (1940) I/II	India-1964 I mean[3]	Java V mean[3]
10	24	15	24	26	34	27	33	38	44	38	43	51	54	44	52	63	63	56	65
20	32	23	33	44	45	39	45	56	58	55	57	68	70	63	70	80	83	79	82
30	37	30	38	57	51	47	51	68	66	65	66	81	81	74	83	93	96	92	95
40	40	35	41	64	56	54	56	77	73	73	72	91	89	83	89	104	105	102	104
50	43	40	43	66	60	60	60	83	78	80	77	99	96	90	95	114	113	110	112
60	46	44	45	71	64	65	63	88	83	85	81	105	101	96	99	122	119	117	118
70	48	47	48	74	67	69	66	92	86	91	85	109	106	101	104	127	125	123	124
80	50	50	50	76	70	73	69	94	90	95	89	112	110	106	108	130	130	129	129

[1] Height indicated is curved value for the mean of the 100 trees per acre of largest diameter.

[2] India-Burma Yield and Stand Tables, 1940.

[3] A published subdivision of the indicated quality class.

[4] Yield and Stand Tables for Plantation Teak, India, 1940.

[5] Von Wuelfing, 1932.

[6] Bourne, 1921.

corresponding quality classes of the 1940-India-Burma yield table with the 1964-India yield table, Bourne's Nilambur table and Von Wuelfing's Java table. The 1940 table height trends correspond with those of Java but in the 1964 table, heights of all site qualities at ten years are appreciably less than those of the 1940 table, though they catch up with them at a later age. The same is true of the relationship between the 1964 table and the Java tables. There is less difference between the 1964 table heights and those of the 1940, and the Java tables beyond middle age. The trends of the 1964 height curves, in early youth, are steeper than those of the 1940 and of the Java tables and, in this respect they resemble those of Bourne's yield tables. In the inferior site qualities of the 1964 tables, the height curves are not so steep as those of Bourne's corresponding qualities, but in the better qualities the height curves are steeper than Bourne's. While the lowest quality of the 1964 table generally follows the trend of the corresponding V-bottom of the 1940 table after middle age, the highest quality of the 1964 table (I—top) is about one-half quality below the 1940 table. The lowest (IV-bottom) quality of the 1964

Local Yield Tables.

Mysore. Table 8 summarizes yield of plantation teak on best quality sites in Chikagalur district, Mysore.

Table 8 Yield of plantation teak, local I quality site, Lakkavalli Range, Chikmagalur district, Mysore[1]

Age (years)	Trees per acre	Basal area per acre (sq. ft.)	Average diam. (in.)	Average height (ft.)	Volume, 9+" in girth (cu. ft.)	Thinnings 9+" in girth (cu. ft.)	Final yield (cu. ft.)	Mean Annual increment (cu. ft.)	Current annual increment (cu. ft.)
10	545		5.03	21					
20	330	85	6.92	40	800		800	40	80.0
30	170	102	10.07	57	1,520	250	1,770	59	97.0
40	134	123	12.27	72	2,300	210	2,510	69	74.0
50	115	128	13.84	83	3,000	120	3,120	71	61.1
60	101	131	15.10	92	3,630	50	3,680	71	56.0

[1]Quart. Jour. Mysore Forest Assoc., 1919, 2:2; Pp. 153-160.

Nigeria. Statistics on growth rate and yield of teak on plots in Nigeria are shown in Table 9.

Table 9 Statistics from periodic measurements of teak in Nigeria.[1]

	Plot 1		Plot 2	Plot 3	Plot 4	Plot 10
	1928	1932	1930	1930	1930	1931
Age of crop, years	16	20	17	15	15	8
Trees per acre, after thinnings	460	220	270	224	426	470
Main Crop						
Average height of largest trees, feet	62.5	62.0	78.0	76.5	74.0	52.5
Average height of crop feet	52.5	60.5	75.0	74.0	68.0	51.0
Diam. breast high inches	6.0	7.1	8.8	8.3	6.8	5.5
Basal area per acre, sq. ft. after thinnings	70.5	48.6	93.3	69.5	85.1	63.9
Volume per acre under bark, cu. ft.	1,067	890	2,447	1,677	1,868	871
Bark, per cent	32.0	29.5	21.5	18.3	21.0	25.0
Intermediate Yield Thinnings						
Number of trees	367	241	120	329	217	283
Average height, ft.	31.5	49.0	61.0	55.5	67.0	44.0
Diam. breast high in.	2.9	5.4	5.7	5.1	6.8	4.1
Basal area per acre, sq. ft.	13.4	30.3	17.2	47.7	37.6	20.8
Volume per acre, under bark, cu. ft.	33	539	278	916	754	204
Total Crop						
Basal area, sq. ft.	83.8	79.1	110.5	117.2	122.7	84.7
Volume per acre under bark, cu. ft.	1,100	1,429	2,725	2,583	2,622	1,075
Mean annual increment, cu. ft.	69	85	160	172	175	134

[1]Oxford Forestry Memoirs, No. 18, 1934, Pp. 11-14.

Trinidad. Teak has become an important building timber, in Trinidad and ranks fourth (1954) among the popular woods, fast replacing the native *Mora excelsa* (Lamb, 1957). Table 10 shows yields of teak on two sites in Trinidad.

Table 10 Yield per acre of teak plantations in Trinidad (Volume down to 9 inch girth, 2.8 inches diameter)

Age (years)	Standing crop after thinning Number of trees	Mean d.b.h. inches	Mean Height of dominant trees feet	Stemwood Volume cu. ft.	Thinning Stemwood cu. ft.	Total yield Stemwood cu. ft.
			Good Plantations			
5	515	4.4	51	636	242	878
10	260	7.2	64	1,171	471	1,884
15	160	9.1	73	1,553	470	2,736
20	110	10.7	79	1,782	459	3,424
25	80	12.0	84	1,909	484	6,035
30	60	13.2	87	1,973	407	6,506
			Average Plantations			
5	600	3.8	42	382	127	509
10	310	5.7	54	815	572	1,514
15	200	7.6	64	1,177	339	2,215
20	150	9.1	71	1,476	286	2,800
25	110	10.4	78	1,680	280	3,284
30	85	11.3	83	1,807	280	3,691

Mean heights of dominant trees when compared with the top heights published for India (1964) indicate that good teak of Trinidad is above quality 2.0-I for ages 5 and 10, but drops to quality 1.0-I by age 20 and sinks further by age 30. The quality of average teak plantation of Trinidad is equal to 2.0-I in the 5th year, drops to about 1.0-I at 10, sinks to 0.0-I at age 20 where it remains at age 30.

The number of trees per acre is about equal to that of the India 1964 tables, quality I, being slightly less in the 5th year and slightly more between the 10th and 25th years for better quality plantations of Trinidad, while the average quality plantations appear underthinned compared to India quality I/II.

Volume

Volume Tables.

Volume tables for teak in Madhya Pradesh and Maharastra were prepared by V. K. Maitland in 1924 (Maitland, 1925). These were based on measurements taken by him on 2,000 teak trees from local standardized qualities I, II, III and IV in West Chanda, Melghat, Nagpur-Wardha, and Hoshandabad divisions. The qualities are defined by the maximum heights of mature trees, being over 90 ft. for class I, and 71 to 90ft., 51 to 70 ft., and under 50 ft. for classes II, III and IV respectively.

The basic tabulation (Table 11) shows volumes, by quarter-girth

Table 11 Volume of timber in the round including bark, quarter-girth measurement - by girth and height classes, to the nearest ½ cubic foot.

Girth Class (inches)	Min. Diam of Class (inches)	Total Height Class (feet)				
		11-30	31-50	51-70	71-90	91-110
		cubic feet				
7-10	2.2					
10-13	3.2	½	1	1½		
13-16	4.1	1	1½	1½		
16-19	5.0	1	2	3½		
19-22	6.0	1	2½	4		
22-25	6.9	1½	3	5	7	
25-31	7.9	1½	4	7	10	
31-37	9.8	2	5½	10	14½	
34-43	11.6	3	8	14	20	
43-49	13.5	4	10½	18½	26	36
49-55	15.4	5½	14½	24	33½	44
55-61	17.0	7½	19	30½	41	52½
61-67	19.2	10	23½	37	49½	62
67-73	21.1	13	28½	44	58	72
73-79	23.0		34	51½	67½	83
79-85	24.9		40	59½	77	94½
85-91	26.7			67	86	105½
91-97	28.6			75½	96½	118½
97-103	30.5			83	105½	129½

measurements, for specific girth and height classes. It can be used directly for estimating volume or for preparing local volume tables. In the latter case quarter-girth and total height must be measured on a sample of representative trees, average girth and height for each girth class computed, and appropriate volumes interpolated to reflect the average height for the class. The volumes so tabulated for each girth class can be used locally in volume estimates without measuring individual tree heights.

Table 12 was developed by Maitland for application to the four local quality classes recognized in Madhya Pradesh and parts of Maharashtra. These quality curves depend on individual judgements in allocating localities to qualities in the field, and selecting individual trees of true average height for the girth in these qualities. The figures given in the tables do not profess to give more than a general average, and only claim to approach accuracy for large number of trees.

RESEARCH

The following problems associated with silvics, silviculture, and management of teak are in need of or under investigation in various countries.

Regeneration of Teak

Phenology. Information is meager on the phenology of teak in various countries and in different parts of the same country, notably in Burma, Malaysia and Java, and in most African countries and those of the Western Hemisphere where teak has been introduced.

Germination. More information is needed on the germinative capacity of teak seed and its variability from year to year, and among countries where the tree is indigenous or under cultivation. It is also necessary to test viability of seed in the shade of natural forest and whether seed lying in natural forest can germinate if full light is given. In Dehra Dun, India, seed viability studies have indicated that seed from Papua and New Guinea (Indonesia) gave maximum germination percentage.[135]

Reproduction. Information is very meager on procuring natural reproduction of teak or managing teak forests by natural regeneration methods. It is known from India and Burma that in medium dry localities, a fairly full stocking can be obtained by clearing the overwood and applying a light burn to the undergrowth; this operation generally helps release suppressed regeneration already existing on the site but does not always induce fresh regeneration. Research is required to find ways and means of obtaining adequate natural reproduction where and when it is wanted. In parts of Central India under certain conditions of overwood and soil and with fire protection, moderate undergrowth of bamboos, teak seems to regenerate with ease. Factors which result in profuse teak recruitment and subsequent establishment of teak seedlings need to be analysed. Sometimes the profuse recruitment obtained at the beginning of the season fails to survive, and it is necessary to know the causes of the mortality and to determine how such seedlings could be made to survive.

Research is also required to determine the number of established seedlings on the forest floor before the overwood is cleared or the taungya is cut and the number found after, and what proportion of the latter are seedling coppice and what proportion seedlings.

Somewhat surprisingly, plantation teak often regenerates easily and profusely in parts of India where it did not occur naturally and in other countries and continents where it is not native. Within its natural range, the floor of a teak plantation is often singularly devoid

[135] Forest Res., in India, 1964-65, p. 29.

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[135] Forest Res., in India, 1964-65, p. 29.

of teak seedlings. It would be useful to determine why teak is able to regenerate naturally in places outside its natural distribution, but not that easily in its own home. This would facilitate the management of natural teak forests and probably lead to a break-through in our knowledge on natural reproduction of teak.

Genetic Studies on Teak

Work on this important subject is meager, and little attention has been given to seed provenance studies, with the result that large areas of plantations, old and young, are not producing the requisite timber in quality and quantity.

Selection of plus trees and formation of seed orchards are urgently required in most countries where teak is under cultivation. Progress of genetic work in several countries is discussed below.

India. The common practice in several states is to collect seed from tall, well-formed seed trees, but this is not always adhered to, and even so, this does not eliminate unwanted characters in the progency.

Progenies from plus trees are now being examined for positive and other characters including growth vigor, morphological variations, changes in chemical constituents, height, length of internode, girth and leaf size. Observations were made on fruit setting differences in different parts of the inflorescence to help selective thinnings of the extra flowers for controlled pollination.

Java. Growth of teak from seed of various origin—Indo-China, Burma, Thailand, India and three localities in Java and Muna in trial plantations 21 years old indicated that Malabar (S.W. India) origin is the best. Next came those of Java origin, followed by Thailand and Burma. Seed of Central India origins showed poor growth.

Teak budding was accomplished with 95 percent success, in large scale budding trials initiated in 1951; scions were taken from 45 to 50-year old plantations with satisfactory results.

Trinidad. A seed orchard has been established. Superior trees have been selected and these are being multiplied by top cleft grafting. Seed of superior genetic quality is expected to be obtained. Experiments are under way on teak spacing, thinning and on drainage of teak soils.

Thinning Research

Information on thinning regimes pertinent to the objects of management and local site quality in pure and mixed crops of teak is meager in most countries. Investigations have to be undertaken to ascertain thinning cycles and optimum grades in different countries and different parts of the same country.

of teak seedlings. It would be useful to determine why teak is able to regenerate naturally in places outside its natural distribution, but not that easily in its own home. This would facilitate the management of natural teak forests and probably lead to a break-through in our knowledge on natural reproduction of teak.

Genetic Studies on Teak

Work on this important subject is meager, and little attention has been given to seed provenance studies, with the result that large areas of plantations, old and young, are not producing the requisite timber in quality and quantity.

Selection of plus trees and formation of seed orchards are urgently required in most countries where teak is under cultivation. Progress of genetic work in several countries is discussed below.

India. The common practice in several states is to collect seed from tall, well-formed seed trees, but this is not always adhered to, and even so, this does not eliminate unwanted characters in the progency.

Progenies from plus trees are now being examined for positive and other characters including growth vigor, morphological variations, changes in chemical constituents, height, length of internode, girth and leaf size. Observations were made on fruit setting differences in different parts of the inflorescence to help selective thinnings of the extra flowers for controlled pollination.

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Classification of trees on the basis of dominance—dominant, dominated and suppressed—has been questioned and a three dimensional concept — spaced, subspaced and ousted — based on the extent of free crown spread, has been suggested.

The age-old Hayers norm for thinning—"frueh, oft, maessig"—begin early, thin frequently, thin moderately—seems to fit perhaps no forest crop better than teak, and in the better quality teak areas of India, notably in Nilambur (Kerala), thinnings normally begin as early as the third year and are repeated at age 6, 10, 18, 30 and 34. Thinnings are generally a heavy "D" grade, and a still heavier grade known as "Advance thinning" has been occasionally practiced, although under heavier grades branching is heavy and natural pruning slow. Many existing thinning research plots are small and suffer from lack of uniformity in thinning treatment.

Very little information is available on methods suitable for thinning teak crops of natural origin which often have a small mixture of other tropical hardwoods.

Protection From Injury and Disease

Research is required on many problems, especially those discussed in the following paragraphs.

Biological control of teak defoliators. The extent of loss of increment is substantial. Mixture including teak and other valuable species can mitigate loss of increment, but cannot eliminate it. Biological control of teak defoliators needs more pointed attention in most countries, especially where teak is native.

Phanerogamic parasites on teak. Among such parasites, the commonest is loranthus. The pest causes loss of increment but is not a rapid killer, and has not therefore attracted adequate attention. It has been demonstrated at the Forest Research Institute, Dehra Dun, India, that species of the same genus infesting *Dalbergia sissoo* can be controlled by introducing certain chemicals like copper sulphate and hormone weedicides such as 2,4-D into the stems of affected trees by boring auger holes deep enough to reach the cambium layer of the trees (Kadambi, 1954).

Wildlife. Elephant and bison where abundant do considerable damage to plantation teak, particularly when it is young. Teak planting in otherwise very suitable locations has had to be abandoned because of such damage. Electric fencing has been found reasonably effective against bison and elephants, and this may turn out to be a useful field for research.

Frost. Frost has been taking a heavy toll of young teak in localities where it occurs, and it has excluded teak altogether from parts of India and other countries with climates and soils which are otherwise very suitable for teak. Natural teak extends into frost ridden localities in Central India and North Burma. Research is required to find frost-hardy natural strains of teak and breed hardy genetic races.

Laterization Of Soils Under Teak

In many teak plantation soils around the world, podsolization and laterization play hide and seek, the equilibrium between the two being delicate. The evergreen and quasi-evergreen forests tend to podsolize the natural soil by accumulation of sesqui-oxides and reduction of $Si0_2$ in the B-horizon, whereas clearfelling the natural forest and creation of pure teak plantation can lead to the washing away of the soluble minerals, leaving behind insoluble silica and sesqui-oxides in the A-horizon. In heavy rainfall areas, soil wash can remove the A-horizon altogether leaving behind the B-horizon which is low in $Si0_2$ and rich in Al_20_3 and Fe_20_3 and behaves like laterite.

Research is required to find out for each locality a suitable undergrowth for teak in situations where podsolization and laterization are delicately balanced. It is likely that in some localities the wisdom of converting the mixed natural forest to pure plantations of teak without first establishing a suitable mixture of ground cover crop for teak would be in question.

The solution of the above problem would pave the way to achieving natural regeneration of plantation teak crops in many countries, and particularly in the semi-evergreen (locally called moist semi-deciduous) forests of West Africa, where teak regeneration under mother trees is often profuse, creating a situation which would probably bypass the need for clearfelling of the forest canopy of a teak crop from rotation to rotation.

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