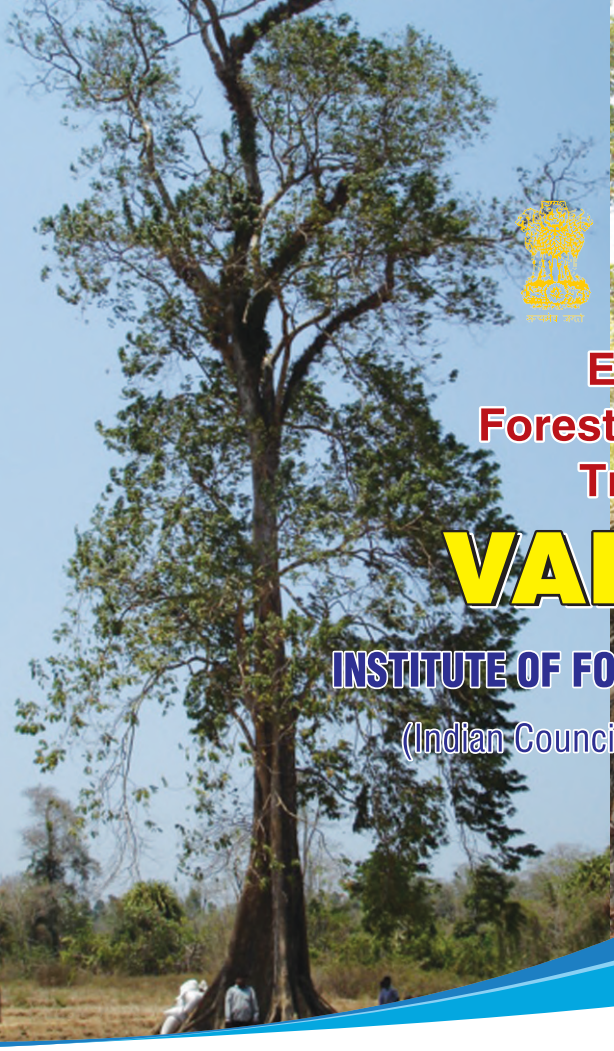

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VAN VIGYAN

INSTITUTE OF FOREST GENETICS AND TREE BREEDING

(Indian Council of Forestry Research and Education)

In this issue

From the
Director's Desk

The ENVIS Centre on Forest Genetic Resources and Tree Improvement at IFGTB functions with the major objective of cataloguing the existing information and knowledge on forest genetic resources (FGR), a prerequisite for executing various action plans towards conservation and sustainable management of FGR at various levels as stated by the UN. 'Know Your Trees' of the present issue bears information about *Pterocarpus dalbergioides,* a highly endemic species of the Andaman Islands. Commonly known as the Andaman padauk or Andaman redwood, information about this valuable semi-deciduous to evergreen tree is scanty and hence has been categorized as a data deficient species by the IUCN. The ENVIS team hopes that the information provided here on padauk will be sufficient enough to shed light on its distribution, biology and necessary conservation requirement of the island species. As plenty of silvicultural options are available for tropical plantation forest management, the research article published in this issue experiments the potential of Casuarina trees as a windbreak system in enhancing radial growth of teak trees in bund planting. Besides, it contains the list of recent journal publications related to FGR.

The newsletter *VAN VIGYAN* serves as a forum for dissemination of FGR information to researchers, academicians and tree growers. It also equally looks forward for valuable suggestions and feedbacks from its readers.

R.S. Prashanth
Director

Know Your Trees – *Pterocarpus dalbergioides* Roxb.

Distribution and Habit

Padauk (*Pterocarpus dalbergioides* Roxb.) is a narrowly endemic exquisite ornamental timber tree belonging to the family Fabaceae. Its natural distribution is restricted to the Andaman group of Islands, India with about 150 large small Islets in an approximate land area of 6400 km^2. Annual rainfall in the region varies from 2400 to 4000 mm and the temperature ranges from 18 - 32°C.

Padauk is a very large semi-deciduous or practically evergreen tree with large butresses (Troup, 1921). It grow upto 45.0 m in height and 5.5 m in girth with usually a clean cylindrical bole up to 15 m above the buttresses. Sufficient data on distribution, economic traits and natural regeneration are available for most trees in Andaman group of Islands (Troup, 1921). Yet IUCN catalogues Padauk as a data deficient species (www.redlist.org). Detailed information on reproduction and life history traits of the species are definitely inadequate (Ganapathy and Rangarajan, 1952). Investigations on these lines are mandatory to develop effective breeding and conservation strategies for managing the genetic resources of padauk.


Photo courtesy Dr C.Kunhikannan

Reproductive biology

Phenology

Padauk sheds leaves in April and new flush initiates by early May. In the initial stages foliage is yellowish green in colour and eventually turns dark green within a week. Considerable variations exist in phenological response among and within populations. Flowering patterns vary within and among populations. In South Andaman trees are practically evergreen and in a partial leafless state only for two to three weeks. However, populations in Middle Andaman and patches of North Andaman have an extended leafless phase. Further in dry patches leaf shedding starts as early as February.

Floral buds develop only after complete leaf flushing. They are dark brown in colour and are produced in thousands on individual trees. Entire crown of the trees flower profusely and are recognizable from very long distances. Flowering is staggered, not all individuals within a population flower simultaneously. Flowering rhythm in Padauk is quite unusual, individual trees flower once in two days and not on all days.

The southern populations flower ahead of those distributed in the north and middle of Andaman. Fruits are completely mature by late November and are harvestable during late January through March.

Floral and pollen biology

Inflorescence is a raceme, each subtending 12-24 flowers, eight to ten such units get compounded on terminal branches. Flowers vary in colour from bright yellow to orange yellow, bisexual, sub-sessile and zygomorphic. They are very fragile, open only for a day and abort in masses during heavy rains. The flower is typically papilionaceous with a standard petal in 15 mm in length and 10 mm in breadth. The wing petals are 7.0 mm in length and 5.0-6.0 mm in breadth. The keel petals are 4.0 - 5.0 mm in length and 3-3.5 in breadth.

Flowers unwind in nights (21.00 hrs) and are completely open by 5.30 hrs. Padauk exhibits temporal dichogamy. Flowers are weakly protandrous, anthers start dehiscing by 06.30 hrs and end by 7.30 - 7.45 hrs. Each anther produces 3600 ± 120 sticky pollen grains that are highly fertile (99 percent). The stigma protrudes well above the stamen (4-5 mm) and curves downward ensuring spatial separation. The stigma is of wet type and receptive by 7.45 – 8.00 hrs. Control pollinated pistils show about 11 ± 4 pollen grains traversing the style at this state. During peak receptivity (at 11.30 hrs) pollen tube count in style steadily increases to 22 ± 6. Pollen count declines to 8 ± 2 pollen by 12.30 hrs and the stigma is practically dry by 15.00 hrs.

Self and crossed pollen do not exhibit any significant difference in growth pattern and fertilization. Under heavy rains anthesis is prolonged. Consequently with no visitors flowers abort in masses. Petals start abscising 12.30 hrs and by 16.30 - 17.00 hrs most flowers are naked exposing the staminal column. The style and stigma remain intact until the first two weeks. The base of the developing ovary is clothed with dark coloured uni-seriate hairs. The calyx along with stamens persists on fruits even after complete maturation. Ovaries contain only two ovules. Young fruits are linear in shape during the first week and become dorsi-ventrally flat round samara within three weeks.

Insect visitors

No large visitors like bats and birds were recorded; only diurnal pollinators were noticed. Taxonomically wide

diverse taxa of insects like Honeybees (*Apis dorsata, Apis cerana indica, Apis mellifera*), Bumblebees, Wasps and Hawk moths visited the padauk. Among the bees *Apis dorsata* was found to be the major visitor (50-60 percent). A sizeable number of thrips were also found residing within flowers. The most visiting insect group was honeybees followed by bumblebees, wasps and hawk moths. In terms of foraging efficiency, honeybees exhibited the longest duration of stay on flowers and the least was by sphingids.

Open and control pollination

Open pollination fruit set varies from 1.9 - 6.4 percent. In control pollination, fruit set in cross pollen was higher than self. No fruit set was noticeable in apomixis. Self and crossed pollen are equally effective in fertilizing ovules and fruits develop regardless of the pollen quality. In most fruits only one ovule matured into a seed. Fruit set in cross-pollination is higher than in self-pollination. Padauk fruit is a winged Samara that grows rapidly into full size within a period of 2-3 weeks.

Seed filling and size

Among the twelve populations studied, fruits with single seed set was the commonest trend (41-57 percent).

Fruits with no seed filling varied from 13-35 percent. Two seed filling was found to be 11-40 percent. Rarely three seed filling was also noticed in most populations 1-8 percent. The shape of Padauk seed is quite distinct when compared to other species. The seed is of sickle shape. Its size seems to be constant in most populations except that the Long Island collections which showed large sized seeds.

Silviculture

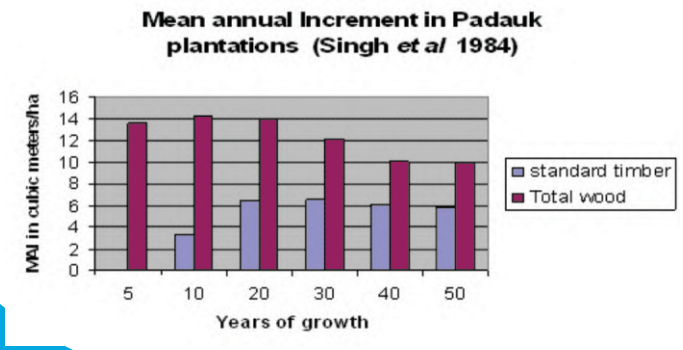
Padauk has been the most valued forest revenue resource over a century in the Andamans. In the history of ornamental timbers, it is perhaps the most exploited species. During the pre-independence history, Padauk

was preferentially extracted from the wild and used for various structural and ornamental uses. To ensure its availability in posterity, the first series of plantation experiments in Padauk started in the South Andamans between the years 1883 and 1889 (Troup, 1914). The success noticed in these trials prompted the colonial

foresters to develop extensive pure padauk plantations in Kalatang and a mixed species trial with *Lagestroemia hypoleuca* in Wimberleygunj during 1903-04. Both the trials were raised in typical Padauk bearing areas by dibbling seeds in regular intervals usually in 2 x 2 meters spacing. Saplings commenced to form a complete canopy in five to seven years. Outside the natural distribution range Padauk was introduced into different parts of Burma. Except in a few sites it failed due to inadequate planning and silvicultural inputs. Padauk was also introduced in to the Western Ghats and North Eastern regions and found to naturalize successfully (Troup, 1921).

Volume and Increment

In Andamans, Troup (1921) recorded trees measuring 87cm in girth and 21m in height at the age of thirty. He found that the rate of growth in plantations to be considerably faster. Troup (1921) opined that with careful site selection and regular thinning regimes more rapid growth could be attained. In the recent past, studies on provisional growth estimates have indicated an MAI of about 6 M^3 at 20, 30, 40 and 50 years (Singh *et al.,* 1984).

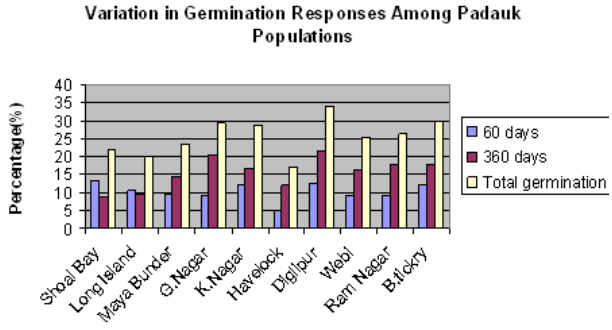


Despite the success as a plantation species not much effort was made in Andamans to popularize Padauk. In the 1960s several plantations were made in different parts of Andamans. Plantations were developed in very different soil formations like Little Andamans and as far as Nicobar from its natural distribution. In the mainland, Padauk is well naturalized in Kerala and it is reported to flower and fruit well. Recently, in 2006 a successful experimental plantation has been raised by the research wing of the Andhra Pradesh Forest Department at Rajahmundry, a typical riverine locality. Success of Padauk in varying agro-climatic conditions indicates its high adaptable qualities.

Passport data on variations and life history traits is very important to manage forest genetic resources. Surveys were conducted in different parts of Andamans to locate plus trees. Seeds were collected from these selections for progeny testing. The Andaman Forest Department took steps in the early 1990s to develop improved planting stock. In technical collaboration with Institute of Forest Genetics and Tree Breeding, the Department has converted two Padauk plantations in the South and Middle Andamans into seed production areas (SPA). Information is now available on the reproduction of Padauk. Detailed studies were conducted in twelve study sites for three consecutive years to obtain information on reproductive aspects such as phenology, floral biology and seed formation.

Nursery studies

Low seed filling is reportedly a common phenomenon in Padauk (Troup, 1914). A comparative study on seed set among the twelve populations revealed that 13-35% fruits were without seed filling. Fruits with single seed set were



common (41-57%) followed by two (11-40%) and one seed filling (1-8%). Continuous extraction in wild leads to genetic drift and padauk was not an exception. Troup (1914) was the first to identify signs of genetic bottleneck in Padauk. His field records on natural populations indicated preponderance of large stems (> 5-7 feet in girth), poorly represented mid size (2-3 feet in girth) and young crops (1 foot). Troup (1914) concluded that with very few seedlings emerging in the wild, regeneration was woefully inadequate in Padauk.

Ganapathy and Rangarajan (1962) in their study on nursery behaviour of twelve Andaman tree species found that Padauk exhibited the least success in nursery. A significant proportion of weak seedlings were observed within seedlots that eventually failed to survive. In tropical trees with massive crowns and profuse flowering self-pollination cannot be averted (Hedegart, 1973). A similar trend has been noted in the nursery behaviour of *Pterocarpus santalinus* (Rao and Raju, 2002). Recently, a detailed study was conducted to quantify seed bank and germination behaviour in Padauk at the Kalatang model nursery. Seeds were sampled from forty trees from each of the ten locations. One hundred seeds from each of the forty trees per location were sown in four replicates and observed for a year. The initial germination responses until sixty days were similar to the observations of Ganapathy and Rangarajan (1962). However, it was found that significant proportion of seedlings emerged until one year after sowing. Ganapathy and Rangarajan reported about 45% of germination, in our estimation a highest germination of 32% was recorded in Kaal Baghan, Diglipur. In general locations like Havelock with very large trees (over 4 meters girth) and low tree density (2-3 trees/ha) showed very poor germination as low as 17%.

Domestication and Genetic Improvement

During the late 1990s Padauk Seed Production Areas (SPAs) were established in the South and Middle Andamans. Thinning was carried out according to the standard SPA establishment methods. At the time of conversion it was assumed that selections were reproductively fit and all individuals within the SPA would randomly mate. However, recently studies indicate that not all individuals within a population flower simultaneously.

Ex situ and *In situ* conservation

Based on the detailed surveys and other life history traits recently during September 2008 two provenance resource stands were developed in Kalatang and Portblair. These trials constitute seed sources from ten different populations. The Kalatang trial has been planted in 3.5 x 3.5 m espacement while the Port Blair trial has been planted in 5x5 m. These trials would serve in testing provenance variations and as demonstration plot. In future, lands need to be identified in typical Padauk growing areas and more *in situ* and *ex situ* conservation stands need to be developed. It would be highly desirable to assemble based on their geographical relatedness.

Yield and Uses

Padauk has broad heartwood in a gorgeous deep pinkish red color with narrow gray sapwood. In international trade, padauk timber is referred to as East Indian Mahogany or Vermillion. It is suitable for panelling, furniture, veneer, ply, carving and making musical instruments and is priced about Rs. 40,000 m^{-3}. In terms of retention of shape, shear and hardness it is estimatedly superior to teak (Nagarajan and Kala, 2006).

Future

Studies on life history traits lead us to understand that variations are ample in Padauk. Phenological behaviour is in harmony with the South West monsoon and there is clear trend of latitudinal effect in the Andaman group of Islands. Populations that are significantly phenologically unique need to be treated as gene pools. Nursery studies indicate high out crossing rates and optimal reproductive success in most populations. The estimates are comparable to most other tropical trees. In the Northern regions Padauk seems to show higher reproductive success. However, it is equally important to note that there signs of inbreeding depression in the Havelock and Long Islands. It is inferred that this could be due to low tree density in the region or due to restricted pollen movement. More studies should be conducted in the Natural Regeneration Areas (NRA).

To rationally manage the existing genetic resources in Andaman Padauk, assessing variation through conventional field testing could be expensive in terms of time and finances. Alternatively, variations could be ascertained using DNA markers. This approach will allow comprehending overall gene diversity, population genetic structure and patterns of gene flow and thereby allowing

development of both a biologically meaningful framework for *in situ* conservation and targeting of sources for sustainable and diverse plantation and restoration efforts. Management strategies based on molecular data are already in the practice in the case of *Pterocarpus macrocarpus* (Leingseri *et al.,* 1995) and *P. officinalis* (Occasio *et al.,* 2002).

In future the following aspects deserve more attention

- The genetic quality of the seed output of the recent established SPAs
- Quantification of variation in wood properties among populations
- Estimation of the proportion of timber colour variants within and among populations.
- Studies on the said issues would allow for a sustained utilization of the genetic resources of Padauk.

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WINDBREAKS OF CASUARINA FOR TAILORING GROWTH AND BRANCHING PATTERN OF TEAK TREES IN BUND PLANTING SYSTEM

Abstract

Teak (*Tectona grandis* L. f.) trees when planted in boundaries or in farm bunds as a row planting attain stunted height growth and develop heavy branchiness on the apical region of the main stem. This stunted growth of teak is also recorded in block plantations of grown in windy localities and on upper hill slopes exposed to strong wind forces. Hence, it was hypothesized that protective measures against wind effect will benefit the teak height growth and will minimize the branchiness in main stem. To test this hypothesis, a study was conducted by establishing windbreaks of casuarina on either side of teak tree row in boundary planting. The expected result was that windbreaks of casuarina will tailor the growth and branching pattern of teak by minimizing the desiccating effect of strong wind on teak terminal shoot growth. These windbreaks on either side of teak row will also provide competition for light to enhance height increment in teak, as teak is a strong light demander species. In this study, superior clone of casuarina was planted at 1 m interval in the outer rows. Teak was planted in the middle row at 2 m spacing. The results of the study clearly indicated that girth and height growth of teak was corresponding to the girth and height growth of casuarina in adjoining rows. Self pruning of branches in teak tree in the mid of casuarina windbreaks was also observed. Hence, it is concluded that teak height growth is determined by height of protective casuarina windbreaks, particularly in windy localities. The branchiness in teak trees also can be altered by establishing them along with windbreaks of casuarina, when teak is grown in bund planting system.

Key words : Windbreaks, Teak, Branchiness, Casuarina, Bund planting

Introduction

A windbreak is a narrow row of trees planted in fields bordering a farm plot (IDF, 1981). Webster on-line dictionary defines windbreak as 'Hedge or fence of trees designed to lessen the force of the wind and reduce erosion'. It is reported that the term "Windbreak" was first used in popular English literature sometime during 1886. It is more popular and widely used in developed countries like USA, UK, Russia, Germany than in developing countries like India. On the contrary, windbreak as an Agroforestry system has greater and more vital role to play in developing countries, more particularly with reference to increasing land area under Agroforestry with minimal sink in cultivation area under agriculture. Further, windbreaks have potential to make agro-ecosystem a climate change resilient system through i) enhanced productivity, ii) reduced evapo-transpiration and in turn increased water use efficiency of the agro-ecosystem iii) reduced crop damage particularly in banana cultivation in Tamil Nadu and iv) increasing carbon sequestration in biomass and in soil. Using of such windbreaks to benefit teak cultivation in farm bunds has been conceived in this present study.

Casuarina and Teak based Windbreak Agroforestry system

It is reported that teak is a light demanding species (Troup, 1921) and hence when grown on bunds or in boundaries of farmland, teak produces profuse branches and in turn height growth is limited and stem form is also bent and not straight (Buvaneswaran *et al.,* 2013a). It is also reported that strong wind is a deleterious factor for growth of teak (Saravanan and Buvaneswaran, 2003). This stunted growth of teak is also recorded in block plantations of teak grown in upper hill slopes exposed to strong wind forces (Buvaneswaran, 2004). On the other hand, there are now fast growing branchy varieties (clones) in Casuarina which have been developed for windbreak agroforestry system (Buvaneswaran *et al.,* 2013b). By considering these two facts, an innovative hypothetical model for cultivating teak in windbreak agroforestry system has been conceived. In this model, it is proposed that teak will be grown in the middle row of windbreak and on either side of teak row, casuarina clones will be planted to produce competition for light to teak. This competition will benefit teak for growing tall without much production of side branches. Casuarina trees also act as 'shelter trees' in this system and protect teak as well as agricultural crops from wind damage. Casuarina is also expected to benefit the system with its Nitrogen fixing

ability. As described earlier, this proposed Teak + Casuarina based windbreak agroforestry system will not only produce teak with less branches but also will enhance the productivity of agricultural crops being grown inside this protective windbreak systems. Another important benefit will be reduction in evapo-transpiration loss of water and thereby increases water use efficiency of the agro-ecosystem. A new scope also arises for increasing industrial wood supply and it is estimated that 240 lakhs tons of increased wood production is possible by promoting windbreak agroforestry systems with three years harvest cycle in the state of Tamil Nadu alone (Buvaneswaran *et al.*, 2013c). Similarly, by promoting this Teak + Casuarina based windbreak agroforestry system, import of teak wood in the country can be reduced, as the import of wood and wood products in the country accounts for 6.3 million cu. m with a total import value of Rs. 9800 crores. In this, Teak alone constitutes about 15 percent of total timber imports to India and the major teak exporting countries to India include Myanmar, Ivory Coast, Ghana, Ecuador, Costa Rica and Benin (Manmohan and Kalpana, 2013).

Materials and Methods

Tree species studied

Tectona grandis L. f.

Teak (*Tectona grandis* L.f.), a potential tropical timber tree species, is native to Indo-Malayan region. This multipurpose timber has favourable strength properties besides having resistance to termite and fungal attack by the presence of polyphenols. It has been described as one of the most durable timbers of the world. Teak is highly useful timber, which cannot be eclipsed by any other timber. Traditional use of teak poles for electricity transmission and timber for railway sleepers are a time tested testimony of its suitability for outdoor uses. The persistent demand and continued shortfall of its availability make it one of the dearest species in the tropics. The natural teak forests of India are confined to peninsular India below 24° N latitude (Seth and Khan, 1958).The most suitable soil for teak is deep and well-drained alluvium, with an optimum pH range of 6.5 to 8.0 and relatively high content of Calcium and Phosphorous (Seth and Yadav, 1959). Teak grows from sea level to an altitude of 1200 m with precipitation range of 800 to 2500 mm. On a global basis, the total area under teak plantation extends to 5.79 million ha, of which 42.9% is in India (ITTO, 2009).

Casuarina equisetifolia X *Casuarina junghuhniana* hybrid clone

Casuarina equisetifolia X C. junghuhniana hybrid clone was introduced during 1952 by Tamil Nadu State Forest Department. Initial planting stock of this hybrid clone was received from Royal Thai Forest Department (Irulandi, 2012). Bharathi (2012) reported that this hybrid clone recorded greater productivity of 13.9 MT ha^{-1} $year^{-1}$ in an experimental site where in it was grown without irrigation, fertilization and any other cultural practices. The demand for vegetatively propagated planting stock of this hybrid clone has increased in the state of Tamil Nadu due to uniform growth, high yield and good income to the farmers (Seenivasan *et al.,* 2012). Rawat *et al.* (2010) also reported that this male hybrid clone from Thailand is widely grown for its adaptability to different environments, fast growth and desirable stem form. Wood based industries exclusively use this clone in their farm forestry and contract farming programmes on a large scale. However, the potential of this clone for the use in windbreaks has not been explored, besides having good branching traits suitable for windbreaks. In the present study, an attempt was made to use this hybrid clone in windbreak agroforestry system to tailor the growth and branching pattern of teak in the bund planting system.

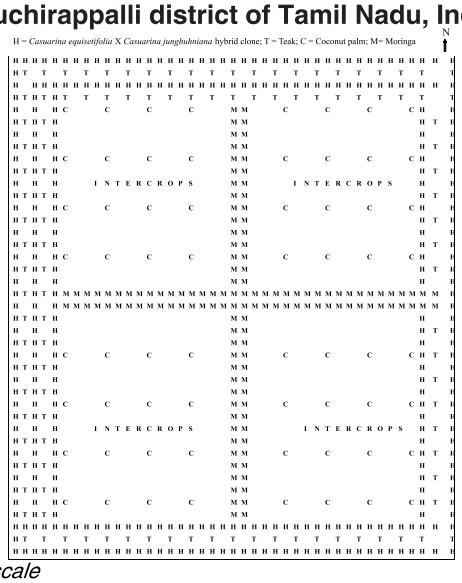
Location of the study

In the present study, 1.63 acres of agricultural fallow land was selected in Puthanampatti village, Musiri Taluk, Tiruchirappalli district of Tamil Nadu, India. 11.069° N Latitude and 78.688° E Longitude can be mapped closest to this village. Altitude is 88 meters above mean sea level. Mean annual rainfall is 566 mm. Average minimum temperature ranges from 5°C to 16°C and average maximum temperature ranges from 8°C to 23°C.

Planting configuration

After land preparation by ploughing, three parallel channels at a distance of 1 m were formed all along the boundary. In the outer two channels, *Casuarina equisetifolia X C. junghuhniana* hybrid clones were planted at 1 m spacing. In the middle channel, teak seedlings were

Figure 1: Schematic diagramme of the experimental farm field in Puthanampatti village, Musiri Taluk, Tiruchirappalli district of Tamil Nadu, India



Not to the scale

planted at 2 m interval. Tree rows were irrigated during the first year at least once in a week. In the subsequent years, no separate irrigation was done for tree rows. The trees will benefit from the management practices followed for the agricultural crops inside the windbreak boundaries. Periodic cultural operations like weeding and soil work around trees were carried out twice a year.

Inside the field, two raised farm bunds were made running across the field, one bund from east to west and another bund from north to south. On either side of these farm bunds, 78 seedlings of Moringa (var. PKM1) were planted at an interval of 2 m. Inside the four blocks of the field, 90 coconut palm seedlings (var. tall x dwarf hybrid) were planted at a spacing of 7.62 m x 7.62 m. The interspaces between young coconut plants were used for cultivating various agricultural crops up to three years period. The intercrops grown were chilly (var. K2), tapioca (local variety), green gram (var. CO6), black gram (var. VBN4), onion (var. CO4), and pumpkin (var. CO1). The schematic diagramme of the field is given in Fig. 1.

Girth at breast height and total height of teak and Casuarina hybrid clone were measured row-wise in all the four directions of the boundary in the farm field at Puthanampatti village in Trichy district of Tamilnadu.

Results and Discussion

Two years after planting, Casuarina recorded a mean

Table 1: Mean height (feet) and girth (cm) of *Casuarina equisetifolia* X *Casuarina junghuhniana* hybrid clone in boundary planting in Puthanampatti village in Trichy district of Tamil Nadu (India)

Casuarina tree rows	Two years growth		Three years growth	
	Mean Height (m)	Mean Girth (cm)	Mean Height (m)	Mean Girth (cm)
Outer C1	5.85	18.0	9.08	21.60
Outer C3	5.94	13.7	8.41	19.20
Outer C6	4.66	13.4	7.68	18.00
Outer C7	3.78	9.1	7.19	16.50
Outer Mean	**5.06**	**13.55**	**8.09**	**18.83**
Inner C2	6.22	19.2	9.81	21.40
Inner C4	5.15	14.7	8.78	21.80
Inner C5	6.19	16.4	9.57	23.60
Inner C9	5.09	13.3	8.17	25.60
Inner Mean	**5.66**	**15.9**	**8.86**	**23.1**
Middle C8	4.11	9.4	7.99	18.60
Grand Mean	**5.22**	**14.1**	**8.52**	**20.70**
SE	**0.3**	**1.15**	**0.29**	**0.96**

height of 5.2 ± 0.3 m and mean girth of 14.1 cm (Table 1). In the third year, mean height recorded was 8.5 ± 0.3 m and girth was 20.7 ± 0.96 cm (Fig. 2,3). Similarly, Bilaidi (1978) studied growth of various tree species in windbreaks and reported that Casuarina attained a height of 6.9 ± 1.6 m in three years' time. Nicodemus *et al.* (2015) reported growth performance of four different species of Casuarina (*Casuarina equisetifolia, C. junghuhniana, C. cristata* and *C. cunninghamiana*) in Coimbatore district, Tamil Nadu (India). They recorded a overall mean height of 15.26 m and diameter of 11 cm at the age of 12 years in block plantation system under rainfed conditions. Greater height and girth recorded in the present study can be attributed to the hybrid vigour combined with irrigation benefits.

It is also observed that height and girth of Casuarina trees in the inner rows (9.08 m height and 23.1 cm girth) was greater than that recorded for trees in outer rows (8.09 m height and 18.83 cm girth). This difference in growth between trees in inner and outer rows may be due to the fact that irrigation and fertilization practices done for the intercrops inside the field could have benefitted the inner tree rows.

The table 2 presents mean height (m) and girth (cm) of Teak in boundary planting. Teak registered a mean

Table 2: Mean height (feet) and girth (cm) of Teak in boundary planting in Puthanampatti village in Trichy district of Tamil Nadu (India)

Teak tree rows	Two years growth		Three years growth	
	Mean Height (m)	Mean Girth (cm)	Mean Height (m)	Mean Girth (cm)
Middle T1	5.12	14.2	6.04	15.13
Inner T2	5.03	16.4	6.64	23.25
Middle T3	4.91	13.9	6.40	19.20
Middle T4	4.48	16.2	6.22	19.40
Middle T5	4.15	12.0	5.97	18.20
Middle T6	3.20	9.9	5.24	13.86
Grand mean	**4.5**	**13.8**	**6.07**	**18.17**
SE	**0.3**	**1.01**	**0.19**	**1.37**

height of 4.5 ± 0.3 m and mean girth of 13.8 ± 1.01 cm at the age of two years. At three years age, height and girth of Teak in the boundary planting was 6.07 ± 0.19 m and 20.7 ± 0.96 cm respectively. Thus, mean annual increment in height growth of Teak is 2.02 m per year in the present study. Earlier study conducted by Buvaneswaran *et al.* (2001) on assessing teak performance in bund planting in a single row without any windbreaks revealed that teak registered a height growth of 8.2, 10.3 and 13.0 m at the age of 5, 9 and 12 years respectively and on an average the mean annual increment amounts to 1.29 m per year. Sharma *et al.* (2011) studied performance of Teak in boundary plantation on Wheat fields in Eastern Uttar Pradesh, India and they also reported mean annual increment in height growth of Teak as 1.21 m per year. While comparing the mean annual increments in height growth of teak in the present study and the earlier studies of Buvaneswaran *et al.* (2001) and Sharma *et al.* (2011), it can be arrived at that windbreaks favours height growth of teak in bund planting system. However, in a wide row alley cropping agroforestry system, teak trees in wide rows (8 m x 4 m) attained height growth of 11 m in 5 years period and mean annual increment works out to be 2.2 m (George and Buvaneswaran, 2004). In the present study, mean annual increment in girth was 6.9 cm per year (Table 2). This increment falls within the range reported earlier by Buvaneswaran *et al.* (2001) for teak in bund planting in a single row without any windbreaks. They recorded mean annual increments in girth to the tune of 5.22, 5.26 and 7.25 cm per year at the age of 5, 9 and 12 years respectively. Sharma *et al.* (2011) reported slightly higher mean annual increment in girth (8.67 cm) for Teak in boundary plantation on Wheat fields.

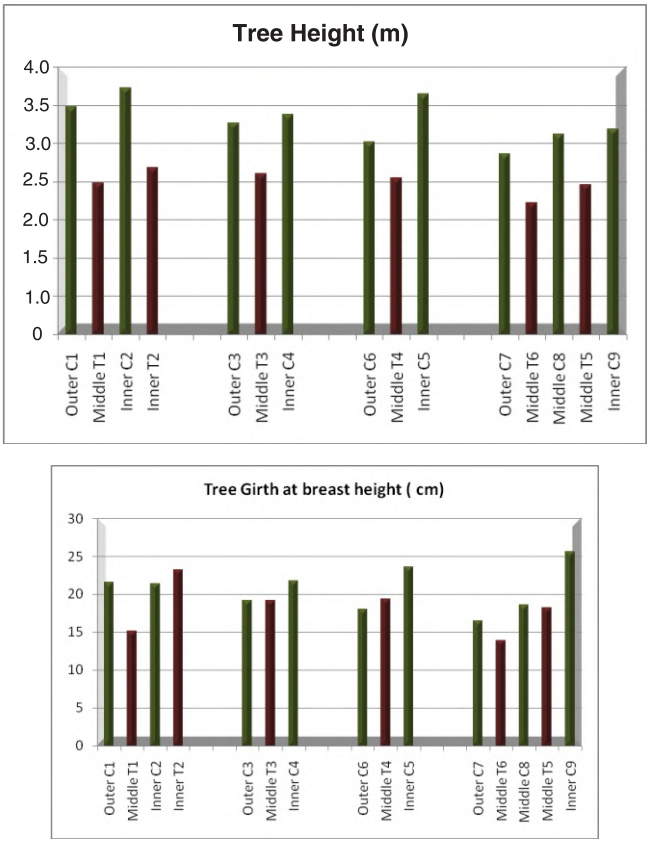


Figure 4: Growth of Casuarina and teak in inner, outer and middle rows in different directions of farm boundaries in Puthanampatti village in Trichy district of Tamil Nadu (Age of trees: 3 years)

While comparing growth of teak and growth of adjoining Casuarina rows in four directions of the farm boundary, it is observed that both girth and height growth of teak was corresponding to the girth and height growth of Casuarina in adjoining rows as depicted in Fig. 4. It clearly indicates that teak height growth is determined by height of protective barriers, particularly in windy localities, irrespective of edaphic and other management factors.

Table 3: Yield of intercrops in the Teak and Casuarina based boundary planting agroforestry system in Puthanampatti village in Trichy district of Tamil Nadu, India (Year: 2012 to 2014)

Cropping sequence	Crop / variety	Yield (kg)	Value realized (in INR)
First crop	Chilly (var. K2)	225 kg (Dry weight)	11250
Second crop	Tapioca (var. Local)	4400 kg	22000
Third crop	Green gram (var. CO 6) (in half of the area)	200 kg	8000
	Black gram (var. VBN 4) (remaining half of the area)	120 kg	4800
Fourth crop	Onion (var. CO 4)	2500 kg	30000
Fifth crop	Pumpkin (var. CO 1)	3600 kg	16200
Bund crop – in Three growing season	Moringa (var. PKM 1) 78 trees	9360 kg	112320
Total value of income from intercrops for three years			**204570**

Fig. 2. Growth of teak in the middle row (Age: 3 years) with windbreaks of Casuarina in Puthanampatti village, Trichy district of Tamil Nadu

Fig. 3. Growth of teak in the middle row (Age: 2 years) with windbreaks of Casuarina in Puthanampatti village, Trichy district of Tamil Nadu

Yield of intercrops and Moringa

Yield of intercrops and Moringa is presented in Table 3. In the first three years, the tree-agricultural crops interaction was negligible. However, the yield from annual moringa (variety PKM1) grown inside the windbreaks recorded yield of 56,160 fruits in three seasons on an average @ 240 fruits per tree which is more than the reported average yield (average yield being 220 fruits per tree for the annual moringa variety PKM1). Smith and Lewis (1972) reported increased fruit set (20 to 30% more) in apple orchards with windbreaks. Gold *et al.* (2013) reported the benefits of windbreaks in fruit orchard as improved crop quality from reduced bruising, better pollination by insects due to less wind. In wind exposed orchards, plant size and leaf area are greatly reduced due to exposures to wind and in turn crop yield can be decreased. Wind-stimulated crops are also known to experience considerable reductions in growth and subsequent yield. A study has shown that wind-induced plant motion immediately elevates cytosolic calcium, indicating the possible involvement of calcium signaling in mediating plant growth responses to wind (Knight *et al.,* 1992).

To conclude, this new approach of growing teak trees along with casuarina windbreaks favours better height growth of teak, particularly in bund planting system and in windy localities. Self pruning of branches in teak tree in the mid of casuarina windbreaks helps to produce clean boles of teak without knots will attract good marketing. Further research on mixed planting of teak and casuarina including in large scale block plantations will pave a way for enhancing quantitative and qualitative production of teak wood in the country.

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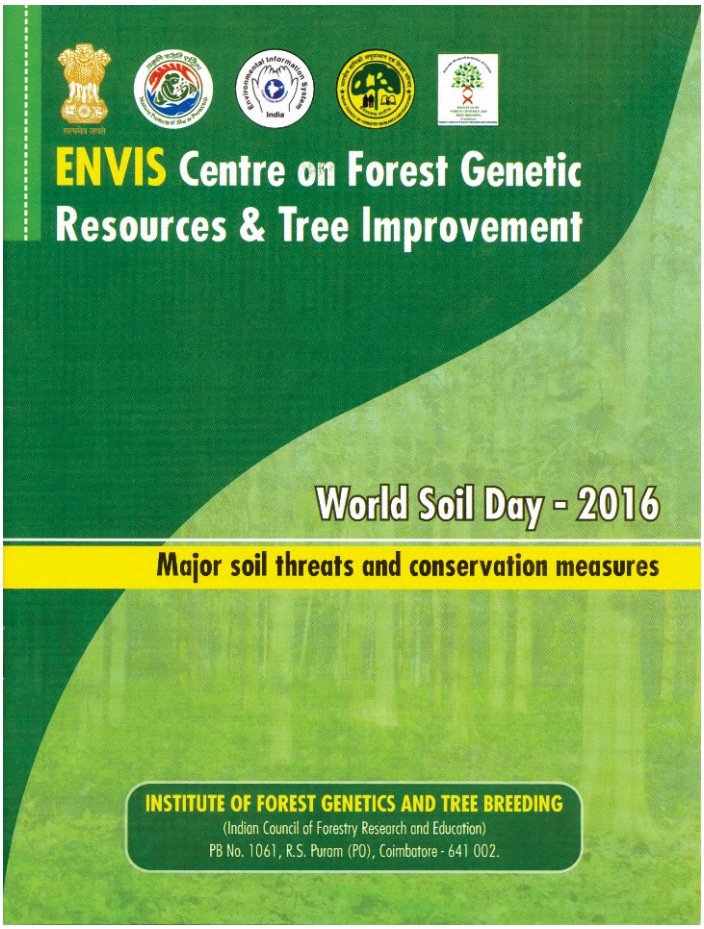
ENVIS ACTIVITIES

Observance of World Soil Day

IFGTB-ENVIS observed the World Soil Day on 5th December 2016. The day was marked with a special awareness program for school students to emphasize them the importance of World Soil Day. Students from nearby schools along with their environmental staff participated in the event. Dr Kannan C.S. Warrier, Co-ordinator ENVIS welcomed the gathering. The Director of IFGTB Shri. R.S.. Prashanth released an information brochure prepared by the ENVIS Centre that explains all major soil threats and their conservation measures. The Director addressed that the students should to be aware about the threats imposed to soil by the exploding human population and the necessity to keep a check on them.

Later the students were taken to Tamilnadu Agricultural University (TNAU) for enabling them to view various soil profiles collected from different locations of south India. Prof. Chandrasekar of Department of Soil Science and Agricultural Chemistry (TNAU) briefed the students about the process of soil formation, different soil profiles, their importance and necessary conservation measures to be followed. The students and their faculty suggested that it was a very useful program as they could realize the crucial role that the soil plays in our life.



ABOUT IFGTB

Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore is a National Research Institute under the Indian Council of Forestry Research and Education. IFGTB envisions a wood secure society. The Institute primarily aims to carry out research to improve productivity of forest tree species through conventional breeding programmes and biotechnological interventions. The major areas of research include tree improvement , breeding, planting stock improvement, marker assisted selection, genomics, clonal propagation, agroforestry systems, climate change research, integrated disease and pest management, seed handling and testing, eco restoration and conservation.

ABOUT ENVIS

ENVIS established by the Government of India, in 1982 has been on providing environmental information to decision makers, policy planners, scientists and engineers, research workers, etc. all over the country. It is a comprehensive decentralized information system on environment involving effective participation of institutions / organisations in the country actively engaged in work relating to different subject areas of environment. A large number of nodes, known as ENVIS Centres, have been established in the network to cover the broad subject areas of environment with a Focal Point in the Ministry of Environment, Forest and Climate Change.

INSTRUCTIONS TO CONTRIBUTORS

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