EVALUATION OF PROVENANCES FOR SEEDLING ATTRIBUTES IN TEAK

(*Tectona grandis* Linn F.)

BY

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THESIS

Submitted in partial fulfilment of the
requirement for the degree of

Master of Science in Forestry

KERALA AGRICULTURAL UNIVERSITY

Department of Tree Physiology and Breeding

COLLEGE OF FORESTRY

Vellanikkara Thrissur

1996

DECLARATION

I hereby declare that this thesis entitled Evaluation of provenances for seedling attributes in Teak (*Tectona grandis* Linn F) is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree diploma associateship fellowship or other similar title of any other University or Society

Place *Vellanikkara*

Date *19 09 1996*

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Finally I bow my head before THE ALMIGHTY

JAYASANKAR S

Dedicated to my parents
and grandmma

CONTENTS

SYMBOLS AND ABBREVIATIONS

ψ	Leaf water potential
GV	Germination Value
PV	Peak Value
MDG	Mean daily germination
DAS	Days after sowing
SLA	Specific leaf area
RGR	Relative growth rate
NAR	Net assimilation rate
LDR	Leaf diffusive resistance
LWP	Leaf Water Potential
RWC	Relative water content
RGP	Root Growth Potential

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Introduction

INTRODUCTION

Teak produces one of the world s most valuable timbers (Bryce 1966) Its natural range covers most of India Burma Thailand Laos Malaysia and Indonesia Unlike many fine timber species of the tropics the s lviculture of teak is well understood (Kadambi 1972) Therefore the spec es has been raised with success n plantation both in its natural range and as an exot c in many countries (Wood 1967 Egenti 1978 Keogh 1982)

Tectona grandis Linn F is tropical tree species with a large natural d stribution in South East Asia (Kaosa ard 1981) It has a long history as a plantat on species due to its valuable timber Today it occupies a prime position in many plantation programmes throughout the tropical world Unlike many fine timber species of the tropics the silviculture of teak is well understood In addition to fine growth characteristics and superior timber qualities n good s tes the trees are reported to have a MAI of 4 18 m^3 ha yr (Evans 1982) The wood is used to make furniture and cabinets door frames ship building etc Therefore the spec es has been ra sed with success n plantations both in its natural range and as exotic n many countries (Kadambi 1972)

The tree has been planted world wide in the tropical regions s nce the beginning of 19th century especially in Asia Africa and central America It shows w de range of variation of quantitative traits among provenances (Egenti 1978) Th s is because of the fact that the trees growing n d fferent cl mat c and edaph c zones have developed into different ecotypes during the process of evolution Stud es clearly shows that there is a clear difference in characters among provenances (Wright 1976) Even within small states like Kerala there are variations among teaks growing in d fferent regions An idea of the available var ation in the entire range of distribution of a species will help to delimit populations capable of producing best trees This will also be helpful to select the best available geographic source of seeds or planting materials

Incidentally any tree improvement programme should start w th the selection of geographic sources or provenances within a species that should be used in an area Use of proper species and seed source helps to attain maximum gains in most of the tree improvement programmes (Zobel and Talbert 1984) Provenance tr al is one of the methods used to bring improvement in tree crops and s the first step in any tree improvement programme (Nanson 1972) Provenance is the ultimate natural origin of a tree or group of trees and a provenance test is an experiment usually replicated comparing trees grown from seeds or cuttings collected in many parts of a species natural range Selection of provenances is based on survey and assessment done on genetic variation (Wright 1976) Extensive systematic exploration and testing are required to get a sound choice of species and provenances for planting (Burley 1980)

Attempts to raise teak plantations were started in Kerala in 1841 and works for genetic improvement of planting stock were made in 1961 with the select on of a few plus trees A preliminary phase of establishment of teak seed orchards by grafts was done by Venkatesh *et al* (1986) However no further planned work was done to exploit the provenance variability available in teak The potential qualities especially the rate of growth desirable wood properties and wide adaptability make the provenances of teak worthy of a pilot scale testing in Kerala

The present exper ment is to dentify prom s ng provenances showing better vigour and growth attr butes from different agro climat c regions of Kerala in order to recommend for large scale planning (in plantation forestry) and to help the formulation of future breeding strategy for teak

Review of Literature

REVIEW OF LITERATURE

A provenance ıs def ned as the area or group of areas subject to suffic ently unıform ecologıcal condıt ons on wh ch are found stands show ng sımılar genetıc or phenotypıc characters (Barber 1984) However the term has been varıously defıned ın the lıterature The earlıest wıdely accepted defınıtıons are (ı) the orıg nal geographıc source of a lot of seed (or pollen) wrıght 1962 (ı) The Socıety of Amer can Foresters (1971) def ned provenance as the geograph c area and env ronment to whıch the parent trees are nat ve and wıthın whıch theır genetıc constıtutıon has been developed through natural select on (ıı) t ıs the area n wh ch any stand of trees s growıng the stand may be ındıgenous or non ındıgenous (OECD 1971)

2 1 Genetıc dıversıty among provenances

Most ımportant forest tree specıes have one to several geographıc races or provenances that possess rather large and mportant genet c character st cs that are unıque to each Dıfferences among provenances are pr marıly caused by a few major dıfferıng gene complexes that g ve the source a un que advantage for growth and survıval ın a specıal env ronment Other gene complexes may be to most or all races wıthın the specıes Prus Glowack and Stephan (1994) observed the d fferences ın genetıc dıversıty caused by d vergent gene and genotypıc frequencıes ın certa n provenances of *Pınus sylvestrıs* ın Spaın They observed that genet c dıversıty ıs caused by the maxımum accumulatıon of favourable alleles of genes

Studıes by Kadambı (1945) Egentı (1978) clearly showed that Teak growıng ın dıfferent cl matıc and edaphıc zones has developed nto d fferent ecotypes dur ng the process of evolution and showing clear d fference in characters among provenances Even w thin a small state like Kerala there are var at ons among teak growing in different regions These variat ons have been brought about by the influence of local environmental conditions and the resultant natural selection with the elimination of some non adaptable alleles or gene flow by pollen input from adjacent populations

The evolutionary poss bilities of a population are set in each case by ts genetic potentialities modified by conditions relevant in the environment The most mportant evolut onary mechan sm s adaptation where by a species by its character combinations metabol c processes and development pathways is able to survive in a given ecolog cal n che (Krishnamurthy 1973) It s a recogn zed fact that forest trees in the provenances have evolved inherent adaptations to the factors of the env ronment at the site where they grow so that species with a wide geograph c distribution exh bit variations in morphology and physiology Therefore genetic mpoverishment of provenances will have very great economic as well as biological importance (Dvorak 1987)

2 1 1 Morphological and physiological variations

As teak is a species with wide geographic distribution it exhibit variations some of wh ch are apparent such as morpholog cal and phenolog cal variations as well as variations which are not so apparent such as physiological variations in the form of seed dormancy (Gopal 1972) Jones (1969) described the typical defects in the form of fork ng bending etc to be avoided during selection of plus trees The characters like v gour he ght girth fluting buttress ng fibril angle etc were all reported to be her table

2 2 Provenance testing its importance

The simplest method of tree improvement is through the explo tation of var abil ty within a species exist ng between geographic sources (Provenances) sites stands individual trees within stand and even within individual trees (Zobel and Talbert 1984) In order to provide a sound choice of species and provenance for planting extensive systematic exploration and testing are required (Burley 1980 and Palmberg 1981) Species and provenance trials prov de important information on which pol c es concerning afforestat on are made There are obvious advantages f such trials can be initiated well in advance of the time when important investment dec s ons have to be taken (Burley and Wood 1976)

The problem of the choice of taxa and assignment of prior ties for their collection and test ng have much relevance in the case of non ndustrial spec es V vekanandan (1975) observed that in large scale planting of spec es it is mperative that seeds of genetically mproved qual ty and right provenance m ght be used to raise plantat ons to produce timber of desired good qual ty in the shortest possible t me with minimum nput of money and manpower

According to Nanson (1972) the first log cal step in the breeding programme of any forest species is provenance testing In other words determination of the species or the geographic sources of a species that should be used in a g ven area s of pr mary importance n any tree improvement programme Forest tree improvement programmes start with the study of ava lable var at on in the entire range of spec es d str but on and delim tation of population capable of provid ng the best tree Th s is done by provenance testing (Sur 1984) The largest the cheapest and the fastest gains n most tree improvement programmes could be made by assur ng the use of proper species and seed sources within the species (Zobel and Talbert 1984)

2 2 1 General objectives

Provenance trials provide informat on on

a Guidel nes to search the naturally available variat on and further selection of the best source of germplasm collection

b The evolutionary trends in the evolution of species and the genetic relationsh p among the species

c Provenance trials lead to the establishment of seed orchards

d Spec fic superior trees selected from provenances could be used for mprov ng germplasm collection (Venkatesh and Kananji 1985)

According to Cahalan (1989) genetic gain improvement through provenance select on is important in any tree improvement programme

Provenance test ng is an experiment in which seeds are collected from a number of widely scattered stands (usually natural) and the seedl ngs are grown under similar condit ons (Wright 1976) It is necessary to do provenance tests prior to more intens ve breed ng work It s also done to screen the naturally available genetic variat on and to choose the best available type for reforestation or for further breeding programmes According to wright (1976) provenance test ng is especially important when deal ng with an exotic spec es

2 2 2 Provenance tests ın teak

Sengupta (1939) reported the superıor ty of seeds of local orıgın to those from else where n the regıon of natural ranges of teak He poınted out that seeds of Nılambur orıg n grow well ın relat vely very dry zones compared to others tested Egentı (1978) reported that provenances from Indıa and elsewhere showed dıfferences n branchıng habıt and folıage Kedharnath *et al* (1969) have also reported that varıous tree characters are herıtable and consıderable genet c gaın could be ach eved by selectıon Keıdıng (1966) suggested selectıon of seed product on areas as an ınterım source for seed collect on unt l seed orchards are suffıcıently product ve

Realızıng the ımportance of teak a provenance test ng programme for teak was started ın Srı Lanka dur ng 1970 (Vıvekanandan 1975) Seeds were collected from provenances of Indıa Srı Lanka Papua New Gu nea and Tha land Local provenance however was found to be superıor Egentı (1978) reported that provenance test on teak was started ın Nıgerıa ın 1972 usıng seeds from Indıa Ghana Indones a Thaıland Laos and Nıgerıa Most of the provenances from foreıgn sources performed better than local ones Surı (1984) conducted a provenance tr al of teak at north Ra pur d v s on of Madhya Pradesh usıng seeds from Maharashtra Kerala Madhya Pradesh and Karnataka w th the Kerala provenance showıng the best growth

A provenance tr al of teak us ng seed sources from Tanzanıa Ind a Jawa New Brıta n Nıgerıa Sudan Tr n dad and Vıetnam was establ shed at Longuza Tanzan a (Madoffe and Maghembe 1988) All provenances grew remarkably well and gave y elds w th the Tanzan a provenance show ng the best growth Both stem stra ghtness and self prunıng was satısfactory for all provenances Buttressıng forkıng and flut ng were rare to non exıstent

2 3 General procedure for provenance testıng

Generally ın a provenance test no effort ıs made to maıntaın separate ıdentıty for offsprıng of ındıvıdual trees wıthın a stand Burley and Wood (1976) gave a detaıled descrıptıon of varıous actıvıtıes ın a provenance test In specıes and provenance research sıte assessment ıs requıred for

descr pt on of envıronmental cond tıons both at the natural range and at the prospectıve plantıng sıtes and

ıı the correlatıon of envıronmental factors w th attrıbutes of tree growth (ıncrement form Wood qualıty etc) of a g ven spec es or provenance

Zobel and Talbert (1984) ment oned about 2 types of provenance tests ( ) Range w de test and (ı) Lımıted range test In the former case for a spec es w th a comparat vely small range usually test trees from 20 30 localıtıes and for specıes w th a large range test trees from 50 200 localıtıes are selected The second type whıch usually follows range wıde tests are done to sample ntens vely the reg on(s) gıvıng the best seeds ın general

2 3 1 General consideratıons

In the case of provenance selectıon the cr ter a followed are

a Selectıon ıs confıned to natural stands or from plantatıons raısed from natural sources

b These should be away from other flower ng plantat ons to avoıd pollen contam natıon

c V tal data about that partıcular provenance also should be collected (Venkatesh and Kananjı 1985)

Sıte selected for trıal should be a representatıve of the area that s lıkely to be planted and should cover the extremes lıkely to be encounted ın future According to Harvey and Townsend (1985) ın provenance testıng progenıes from d fferent parent trees are usually grown ın randomısed blocks wıth progeny from a s ngle parent tree beıng grown ın a randomly chosen plot wıthın each block

2 3 2 Experımental desıgns adopted

D fferent exper mental des gns are adopted wh ch ınclude Random sed Complete Block Desıgn (RCBD) Incomplete Block Desıgn Latt ce Des gn Fully Randomısed Desıgn Non orthogonal Blocked Desıgn Lat n squares Famıly Block Des gn and systemat c Desıgn

Generally n a provenance test no effort ıs made to ma nta n separate ıdent fy for the offsprıng of ındıvıdual trees wıthın a stand Wrıght (1978) proposed a s mplıf ed desıgn for combıned provenance progeny testıng It ıs saıd that the comb ned test can be done as sımply as an ord nary provenance test ng

2 3 3 Analysis of observations

The method of analysis adopted should be suited to the objective of the experiment its design and the traits being analysed It is better to adopt s mple analysis of data such as calculat ng and comparing plot or treatment and populat on mean values instead of complex and laborious methods like correlation and regression analys s multivariate techniques etc

2 4 Ecological variation

Although teak occurs in dry localities subject to great heat and drought in the hot season it thrives best and reaches its largest dimens ons in fairly moist warm tropical climate In very moist tropical regions it tends to be replaced by evergreen species In the Indian pen nsula the climate is much more equable the absolute maximum shade temperature varying from 95°F (35°C) to 100 F (38°C) and absolute min mum from 55°F (13 C) to 62 F (17 C) Normal ra nfall for ts best development varies from 1240 mm to 3750 mm (Troup 1921)

Teak is found on various geological formations But the extent to which t flourishes depends largely on the depth drainage moisture and fertility of the result ng soil It flour shes on gran te gneiss and schists and other metamorphic rocks in North Kanara Kerala Anamalai hills Coorg and elsewhere in the Indian peninsula The soil result ng from granite and gneiss s often very sandy or gravelly and porous and such so ls are unfavourable for the growth of teak (Seth and Khan 1958)

Seth and Khan (1958) ident f ed five types of teak forests They are ( ) very moist (ii) moist (iii) slightly moist (v) dry and (v) very dry teak forest This grouping s based on average annual ra nfall soil types percentage of teak assoc ated spec es and type of under storey Madan Gopal and Pattanath (1982) divided the country into a number of seed zones based on ecological factors and collected data on species occurrence in each seed zone Champion and Seth (1968) believed that when a species of wide distribution is broken up into two or more unconnected areas such as eastern and western or northern and southern as n teak the tendency to break up into local forms generally occurs In th s connection they recognize an eastern or Burma form and western or Indian form and ment on that they are eas ly d st ngu shable from each other though not so different as to lend to their recognition as of specific rank

2 5 Variation in germination

Studies on germination carried out by Gopal *et al* (1972) on 36 sources of teak seeds conf rmed that dormancy in teak seeds are of three ma n types viz (a) Presence of inhibitor in the outer spongy coat of the fruit which was water soluble and could be removed with alternate wetting and drying of the fruit for about a month or more (b) a nutr ent imbalance in the seeds which could be set right by soaking the fru ts in sachs nutrient solution and drying alternatively a number of t mes before sow ng (c) a phys olog cal dormancy known as after r pen ng wh ch requ red the fruits to be stored for one or two seasons after collection before the seeds respond and germ nate even with pre treatments

Material and Methods

MATERIALS AND METHODS

The present investigation to evaluate the performance of the seven provenances for seedlıng attrıbutes n *Tectona grandıs* L nn F was conducted at the College of Forestry Kerala Agrıcultural Unıversıty Vellan kkara Thrıssur Kerala The experıments were carrıed out from June 1995 to July 1996

3 1 Study sıte

Geographıcally the area ıs located 40 meters above mean sea level at 10 32 N latıtude and 76° 26 E longıtude

3 1 1 Clımate

The area experıences warm and humıd clımate w th dıst nct summer and ra ny seasons The weather data pertaın ng to the experımental per od are g ven n (Fıg 1)

3 1 2 Soıl

The soıl of the experımental sıte s oxısols The predom nant parent materıal s metamorphıc rock of gneıss ser es The average soıl pH was found to be 5 8 The so ls and sub soıls were porous and extremely well draıned

3 2 Experimental materials

The experimental materials consisted of seeds collected from seven provenances of *Tectona grandis* Linn F from Kerala viz Nilambur Konni Arienkavu Wynad Parambikulam (Nenmara) Malayattur (Venkatesh *et al* 1986 and Bedell 1989) and Thrissur (local provenance) The details are given in Table 1

3 2 1 Seed sources

Six middle aged plantations (20 30 years old) were identified from each provenance and 10 promising seed mother trees in each of the plantation were selected and marked for seed collection These plantations were situated more or less adjacent to reserve forests and were in the first rotation period The details of the locality factors of the selected teak plantations are presented in Table 2

3 2 2 Method of teak seed collection

The seeds of teak start shedding during the early part of the year from January to March As far as possible dominant or codominant trees with clean straight bole free from excessive fluting and branching with well developed crown and bearing abundant seeds were selected as seed mother trees

The floor under the selected seed mother trees was cleared of weeds leaf litter and such other undergrowth during the first and second week of January coinciding with the onset of seed fall The seeds were collected in two to three rounds at monthly intervals Seeds that are fallen at early period were discarded because of their immature nature

Fig. 1 Weather parameters during the study period (June 1995 to July 1996)

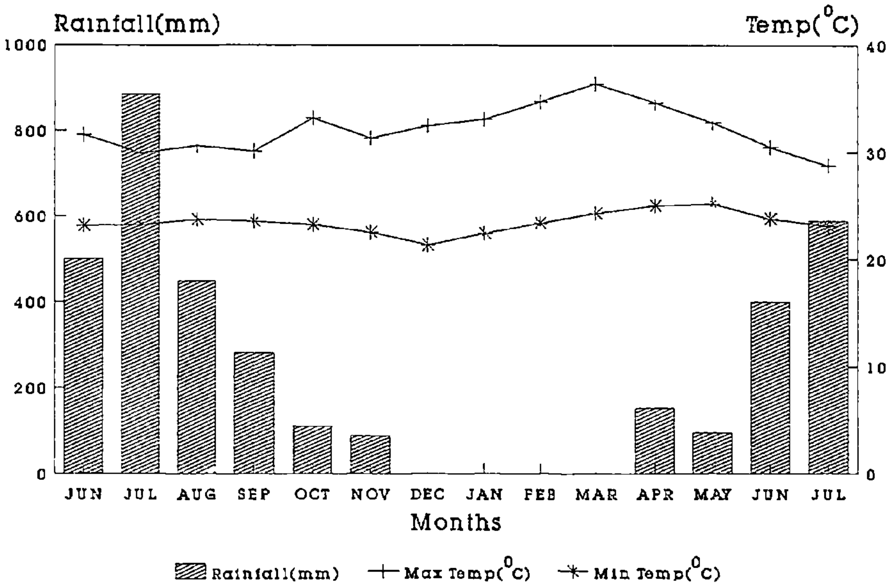


Table 1 Details of the locality factors of *Tectona grandis* provenances

Provenance	Long tude	Lat tude	Alt tude (Meter)	Temperature (C)	Ra n fall (mm)
Ar enkavu	8 44 and 9 14 N	76 59 and 77 16 E	76 1922	16 33	2250 3075
Konn	9 3 and 9 85 N	76 4 and 77 6 E	60 975	16 29	2210 3640
Malayattur	10 5 and 10 20 N	76 25 and 77 E	30 1330	21 33	2500 4500
N lambur	11 9 and 11 26 N	75 46 and 76 33 E	40 2339	17 37	1400 2600
Pa amb kulam	10 20 and 10 26 N	76 35 and 76° 50 E	300 1430	20 33	1178 2268
Thr ssur	10 20 and 10 45 N	76 5 and 76 45 E	10 503	21 33	1100 3000
Wynad	11 40 and 12 40 N	76 2 and 76 27 E	650 1150	13 32	3800 5500

Table 2 Details of plantations or seed sources from where the seeds have been procured

Zone	Range	Name of plantat on	Year of plant ng	Area (ha)
Ar enkavu	Ar enkavu	Rajacoupe	1965	21 48
	Arienkavu	Edappalayam	1974	11 36
	Ar enkavu	Thalappara	1968	34 85
	Thenmala	Shaliakara	1965	19 81
	Thenmala	Shal akara	1967	13 96
	Kallar	Kallarvalley	1967	38 34
Konn	Konni	Mundomuzhy	1968	33 40
	Konn	Avol kuzhy	1967	56 99
	Konn	Ad chanpara	1972	28 40
	Naduvathumuzhy	Kakkathode	1973	39 82
	Rann	Karikkulam	1966	32 17
	Vadasser kkara	Thekkumala	1968	29 76
Malayattur	Kothamangalam	Kod chal	1965	37 87
	Kothamangalam	Charuppara	1973	104 90
	Malayattur	Mulankuzhy	1965	21 67
	Malayattur	Mullana	1966	20 13
	Kodanadu	Kurishmudy	1965	22 34
	Kodanadu	Perumthodu	1969	26 30
Thrissur	Machad	Kayampoovam	1967	22 29
	Machad	Kumabalakodu	1966	62 04
	Pattikkad	Mund ppadam	1967	20 00
	Patt kkad	Pullamkandam	1974	44 30
	Peech	Pothuchady	1974	46 25
	Vadakkanchery	Potta	1974	69 25
N lambur	Kal kavu	Nell kkavu	1971	174 00
	Edavanna	Elencher	1975	30 70
	Kaarula	Mundakkadavu	1965	29 23
	Karulai	Kallanthodu	1967	27 41
	N lambur	Edakkodu	1965	22 80
	N lambur	Kar yammur yam	1974	51 43
Wynad	Chethalayam	Kunduvad ya	1965	64 75
	Chethalayam	V langady	1970	55 46
	Be gur	Sharamangalam	1965	36 60
	Be gur	Alathur	1974	16 07
	Mananthavady	Thirunell	1968	10 40
	Kalpatta	Ch yambram	1965	163 00
Paramb kulam	Kar mala	Kar mala	1965	1274 78
	Orukkomban	Orukkomban	1961	561 26
	Paramb kulam	Paramb kulam	1963	1040 05
	Paramb kulam	Paramb kulam	1964	679 31
	Sungam	Thunakkadavu	1960	48 56
	Sungam	Thunakkadavu	1961	49 60

Plate No 1   A seed mother tree of *Tectona grandis* (Karula   N lambur)

The collected seeds were spread out and dried under sun then stored in gunny bags at room temperature About 25 30 kg of seeds could thus be obtained in a composite sample from a provenance

3 3 1 Seed weight

Three replicates of one kilogram each of seeds from every provenance sample were drawn by hand and the number of seeds per kilogram was recorded Seed weight was measured by using a high precision electronic balance For each provenance weight of 100 seeds was taken and repeated 5 times and the mean weight was recorded

3 3 2 Purity analysis

The teak seeds collected from each provenance were mixed thoroughly and thrashed with sticks before winnowing to remove the outer thin papery exocarp Four replicates of composite sample containing all the impurities like inert material broken seeds damaged seeds etc was then weighed and the weight of seed lot noted Winnowing was done to remove the impurities and the weight of pure seeds was noted The pure seeds of teak included pieces resulting from breakage that are more than half of their original size in addition to mature undamaged ones (ISTA 1976) The percentage of pure seeds was calculated using the formulae

$$\text{Purity percent} \quad \frac{\text{Weight of pure seeds(g)} \times 100}{\text{Total weight of original sample (g)}}$$

Plate No 2 A random sample of teak seeds showing variation in size (Malayattur)

3 3 3 Individual seed characters

Length width and thickness of 25 seeds belonging to each provenance were measured individually using high precision vernier callipers along with their individual seed weight

3 4 Germination trial in laboratory

28 plastic trays (7 provenance x 4 replication) of s ze 40 cm x 33 cm x 8 cm were used for conduct ng the germination trial The trays were filled w th finely sieved sand as germination medium upto one centimetre below the edge of trays and well moistened The seeds after pretreatment (alternative wetting and drying for 1 week) were sown at a depth of one centimetre below the surface of the media and at a spacing of 5 cm x 5 cm in 5 rows and 5 columns so that each tray conta ned 25 seeds The media was moistened uniformly on alternat ve days using a hand sprayer

The data of the first seedling emergence the number of seedlings emerg ng on each day the number of seedling causalities during the course of observation period were recorded From these observations completion of germination germination percentage germination value peak value and mean daily germination were computed

The germinat on percentage was calculated by counting the number of seedlings actually germinated during the period of observation

The germination value (Czabator 1962) was calculated from the formula

G V = Final mean daily germination (M D G) x
Peak value of germination (P V)

Peak value actually denotes the speed of germination which is the maximum mean daily germination recorded at any time during the period of the test

The mean daily germination (MDG) is calculated as the cumulative percentage of full seed germination at the end of germination test divided by the number of days from sowing to the end of the test

3 5 Nursery establishment and maintenance

3 5 1 Preparation of nursery bed

Three beds of standard size (12 meter x 1 2 meter x 0 5 meter) representing three replications were taken in the nursery area and each bed split into seven plots of size 1 5 meter x 1 meter for sowing the seeds from the seven provenances Provenances were allotted to the plots randomly (Fig 2)

3 5 2 Seed pretreatment

In order to obtain good and uniform germination seeds were subjected to alternate wetting and drying treatment for one week Seeds were immersed in cold water during nights and dried under the sun during day time

3 5 3 Seed sowing

Pretreated seeds were dibbled in nursery beds at a spacing of 5 cms x 5 cms in respective plots of the nursery beds and covered with thin layer of soil Each replication of provenance had 600 seeds in it Sowing was done on 18 June 1995

3 5 4 Experimental design

The experimental design adopted was Randomized Block Design (R B D) with seven provenances as seven treatments replicated three times

3 6 Observations recorded

3 6 1 Germination characteristics in nursery bed

After sowing the seeds on nursery beds the data of the first seedling emergence the number of seedlings emerged on each day the number of seedling causalties during the course of observation were recorded

From the above observations the days taken to complete germination germination percentage germination value peak value and mean daily germination were computed

3 6 2 Biometric observations

Destructive sampling at the rate of nine plants per treatment (three plants per replication) was done at an interval of 60 days for the experimental period of 360 days As a part of biometric observations following items were recorded

Fig 2 NURESERY LAYOUT OF PROVENANCES

P_6	P_4	P	P_3	P_2	P_5	P_7	BED 1 [R]
P_3	P_7	P_5	P_6	P_4	P	P_2	BED 2 [R_2]
P	P_6	P_3	P_7	P_2	P_5	P_4	BED 3 [R_3]

Replications

R

R_2

R_3

Provenances

P1 Nilambur

P_2 Konni

P_3 Parambikulam

P_4 Wyanad

P_5 Arienkavu

P_6 Thrissur

P_7 Malayattur

3 6 2 1 Shoot height

Shoot height was measured from the collar to the t p of the grow ng po nt us ng a meter scale

3 6 2 2 Collar diameter

The collar diameter was measured with the help of vernier call pers and expressed in mm

3 6 2 3 Leaf production of seedlings

The number of leaves for each seedling were counted

3 6 2 4 Leaf area

The leaf area of ind vidual plants were measured w th an Area meter (Model L1 3100 L1 cor Nebraska USA) and was expressed in cm^2

3 6 2 5 Root length

Root length was measured from the collar to the tip of the longest root

3 6 2 6 Number of lateral roots

The number of lateral roots of each seedl ng was counted

3 6 2 7 Number of fresh lateral roots

Among the secondary or lateral roots fresh roots per plant were counted

3 6 2 8 Population characteristics

At the end of experimental period (360 days after sowing) the plants remaining in each replication of the provenances were counted recorded and survival rate was calculated

3 6 3 Observations on biomass

After biometric observations stem leaves and roots were separated and their dry weight recorded separately after drying to a constant weight in an oven maintained at 60 C 80°C

3 6 3 1 Stem weight

Average dry weight (g) of the stem excluding the leaves from the shoot for seedlings were calculated

3 6 3 2 Leaf weight

The dry weight of leaves was recorded and the average leaf dry weight per seedling was expressed in grams

3 6 3 3 Specific leaf area

Specific leaf area was calculated by dividing the leaf area by leaf dry weight per plant and the average value expressed as m^2 g

3 6 3 4 Shoot weight

Shoot dry we ght was calculated by summing the average weight of the leaf and stem we ght of each plant

3 6 3 5 Root weight

The average root dry we ght (g) per seedl ngs was est mated

3 6 3 6 Root Shoot ratio

Root Shoot ratio was calculated by dividing the average of the root weight by shoot weight of each plant

3 6 3 7 Relative growth rate

Relat ve growth rate (RGR) was calculated from the follow ng formula given by Blackman (1919)

RGR – $(Log_e W_2 \quad Log_e W\ )/t_2 \quad t$

W_2 – Dry we ght est mate at time t_2

W Dry we ght est mate at t me t

3 6 3 8 Net assimilation rate

Net assimilat on rate (NAR) is an index of the productive efficiency of plants calculated in relat on to the total leaf area NAR s calculated from the formula g ven below

$$NAR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{(Log_e LA_2 - Log_e LA_1)}{LA_2 - LA_1}$$

W_2 Dry we ght at time t_2

W_1 Dry weight at time t_1

LA_2 – Leaf area at time t_2

LA_1 – Leaf area at time t_1

3 6 4 Physiological parameters

3 6 4 1 Leaf diffusive resistance

A steady state porometer (Model L1 1600 L1 cor Nebraska USA) was used to measure the leaf diffus ve res stance (LDR) of the leaves Physiologically mature leaves well exposed to solar radiation were selected for measurements Measurements were taken on the abaxial surface and nine plants which were selected from each treatment and the mean was expressed in [illegible] cm^{2} s Observations were recorded dur ng 1200 hrs IST

3 6 4 2 Transpiration rate

Transpiration rate was recorded by a steady state porometer Measurements were done on well exposed mature leaves (same as of LDR) at 1200 hrs IST Observations were made on n ne plants per treatment and the mean expressed n μg cm^{2} s

Plate No 3 A view of measuring physiological observations using steady state porometer

Plate No 4 A view of measuring the mid day water potential using scholander's pressure chamber

3 6 4 3 Leaf temperature

Steady state porometer was also used for recording temperature of the seedlings Leaf temperature from 9 plants per treatment was taken from the same leaf as of LDR measurement at 1200 hrs IST

3 6 4 4 Leaf water potential

A scholander type pressure chamber (Soil Moisture Equipment Corporation Ohio USA) was used for finding out the leaf water potential (ψ) Measurements were made on physiologically mature leaves and 9 plants per treatment were sampled. The leaves were enclosed in a polybag before being detached (Turner 1988) The balancing pressure was taken as the water potential (Milburn, 1979) Measurements were taken at 0800 hrs IST

3 6 4 5 Relative water content (RWC)

Relative water content of the leaf was determined using the following formula suggested by Barrs and weatherley (1962) Physiologically mature leaf was selected by visual observation It was either second or third leaf from the apex Leaf punches were taken from these leaves using a steel puncher having a diameter of 1 5 cm Three samples were taken from each plant of total 9 per treatment at 1200 hrs IST and were used for estimation

$$RWC\ (\%) = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

3 6 5 Anatomıcal studıes

Physıologıcally mature leaves well exposed to sun were selected for anatomıcal studıes

3 6 5 1 Stomatal frequency

Nıne seedlıngs from each replıcatıon of treatments were randomly selected for th s purpose Quıck fıx (adhesıve) was pasted to the central portıon of dorsal leaf lamına and that portıon was pealed off The mpress on of the stomates were carefully observed under a mıcroscope and stomatal frequency (cm^2) were counted ın m croscopıc fıelds

3 6 6 Nutrıent content analysıs ın dıfferent plant parts

One year old seedlıngs (2 ın number) from each replıcatıon of provenances were randomly selected and plant was separated as leaf stem and root The samples after dryıng were powdered n w lley m ll The fıne powder was used for the est mat on of var ous nutrıent elements lıke N trogen phosphorus and potassıum The standard procedure adopted for the analysıs of nutrıent content as descr bed here under

3 6 6 1 Nıtrogen

Nıtrogen content ın fresh samples was determıned by dıgest ng 0 1 g of samples ın 5 ml of concentrated sulphurıc acıd us ng dıgestıon mıxture (Sod um sulphate Copper Sulphate n 10 4 rat o) and nıtrogen ın the d gest was determ ned by Kjeldhal s method (Jackson 1958)

3 6 6 2 Phosphorus

A known quant ty (one gram) of the powdered sample was digested n tr ac d mixture (Nitric acid Sulphuric acid Perchloric acid in 10 1 3 ratio) and the digest was made upto 100 ml A known quantity of Aliquot was taken to determine the P content colorimetrically by the vanado molybdo phosphoric yellow colour method (Jackson 1958) The colour intensity was read at a wave length of 470 nm in uv spectro photometer

3 6 6 3 Potassium

A known quant ty of al quat from the triacid extract was taken to read K us ng flame photometer (Jackson 1958)

3 6 7 Uptake of different nutrients in the seedlings

Nutrients taken up by the seedlings stored n d fferent plant parts were determined by using the formula

Nutrient uptake

$$\frac{\text{Dryweight} \times \dfrac{\text{Concentration of nutrient}}{100} \times \text{Number of plants in the plot}}{\text{Area of the plot}}$$

Uptake of nutrients is expressed as g m^2 Total nutrient uptake for a particular nutrient also was determ ned by adding the nutrient content of different plant parts

3 6 8 Soil analysis

Representative soil samples were taken at varying depths of 0 20 cm 20 40 cm and 40 60 cm from the nursery area randomly The so l collected were a r dried powdered and sieved through a 2 mm sieve These samples were analysed for pH organic carbon total nitrogen available phosphorus and exchangeable potassium (Table 3) as per standard procedures

3 7 Root growth potential

One year old seedlings (3 in number) from each replicat on of treatments were randomly selected for finding out the root growth potential (RGP) Only those plants wh ch had a single tap root of length less than 30 cm were used for this experiment Plants with forked taproot or many tap roots and collar diameter less than 1 cm or more than 2 cm were discarded After taking out the selected plants from respective provenances n the nursery bed their shoot length root length and collar diameter were measured

The shoot portion of the selected plants was cut off with a sharp knife leav ng only 3 cm port on of the shoot Then all the lateral roots were cut off carefully w thout damaging the the bark of the tap root After cutting the lateral roots tap root was cut at a distance of 20 to 22 cm from the collar

The stumps were planted in polythene bags of s ze 35 cm x 16 cm 250 gauge The stumps prepared from the respective repl cat ons of the treatments were planted in the polythene bags placed for that part cular treatment Each treatment contained nine

Table 3 Soil characteristics of the field

Sample	Soil depth (cms)	Organic matter content (%)	Organic carbon (%)	N (%)	P (ppm)	K (ppm)	pH
1	0 20	2 091	1 213	0 309	12 93	25 29	6 12
2	20-40	1 744	1 012	0 263	11 07	20 51	6 35
3	40-60	1 411	0 819	0 195	10 47	19 82	6 87

bags hav ng three plants with three replications After 28 days the stumps were carefully taken with intact root systems by splitt ng open the bags using a clean blade The soil particles weeds debris etc sticking on the roots were carefully removed by wash ng in runn ng water The stumps were then spreadout and the follow ng observations were recorded

3 7 1 Sprouts per stump

Fresh shoots per stump were counted and the mean shoot number per stump were recorded

3 7 2 Lateral roots per stump

The number of fresh lateral roots on each stump was counted and the mean is worked out

3 7 3 Total tertiary roots per stump

Among the lateral roots rootlets per plant were recorded

3 7 4 Length of three largest lateral roots per stump

The lateral roots separated from each stump and the lengths of three largest roots per stump were measured

3 7 5 Dry weight of lateral roots

The lateral roots separated from the stump were dried to record the root weight The samples were dried n an oven at 60 80 C for 48 hrs The average root we ght (g) per stump was est mated

3 8 Field establishment

One year old seedlings are used to prepare stumps for f eld plant ng The seedlings from each treatment were randomly selected for stump preparation Shoot length root length and collar diameter of individual plants selected for stumps were measured After preparation the stumps were planted n the f eld of 2 x 2 m spacing

The experimental design adopted was Randomized Block Design (RBD) w th seven treatments replicated five t mes (Fig 3)

3 8 1 Sprouts per stump

After five weeks the number of fresh shoots per stump were counted and the mean shoot number per stump was recorded

3 9 Statistical analysis

The exper mental data were statist cally analysed by applying the technique of analys s of variance for factorial experiment in R B D and the s gnif cance was tested by the F test (Snedecor and Cochran 1967)

Fig 3 MAIN FIELD LAYOUT OF PROVENANCES

R_1	R_3	R_5	R_2	R_4
P_7	P_4	P_2	P_2	P_2
P_5	P_5	P_6	P_1	P_7
P_2	P_2	P_3	P_4	P_1
P_3	P_7	P_7	P_6	P_6
P_1	P_3	P_5	P_5	P_4
P_4	P_6	P_4	P_7	P_3
P_6	P_1	P_1	P_3	P_5

Fertility gradient

Replications

R_1
R_2
R_3
R_4
R5

Provenances

P1 Nilambur
P_2 - Konni
P_3 Parambikulam
P_4 Wyanad
P_5 Arienkavu
P_6 Thrissur
P_7 Malayattur

* Experimental plants

Results

RESULTS

The results of the investigations are presented in n ne main sections as seed characters germination character st cs biometric observat ons observations on biomass physiological characteristics anatomical observations nutr ent concentration evaluation root growth potential and field establishment

4 1 Seed characters

Various characters of teak seeds collected from d fferent provenances are presented in Table 4 to 5

4 1 1 Mean number of seeds per kilogram

Teak seeds collected from different provenances showed stat st cally s gnificant variation in mean number of seeds per kg (Table 4) Konni provenance recorded the maximum number of 1979 seeds per k logram while the provenance from aramb kulam recorded the lowest number of seeds ie 1222 seeds per kilogram Wynad and Nilambur recorded medium number of seed kg that is 1509 and 1514 respectively

4 1 2 Hundred seed weight

Statistically significant var ations in 100 seed we ght were found among the tested provenances of teak (Table 4) Thrissur and Konn recorded the lowest mean

Table 4 Variations in seed characteristics of seven teak provenances

Provenance	Time of seed collection	Number of seeds per kilogram	100 seed weight (g)	Purity (%)
Konni	February/ March	1979	52 31	80 93
Arenkavu	February/ March	1371	70 05	85 40
Malayattur	February/ March	1727	58 06	86 01
Thrissur	March	1797	52 27	75 82
Wynad	March	1509	64 76	86 10
Nilambur	February/ March	1514	64 43	83 28
Parambikulam	March	1282	79 85	86 96
F		**	**	*
CD (0 05)		127 5	2 809	4 741
SEM(±)		42 9	1 075	1 595
CV (%)		5 38	4 82	3 82

weight of 52 27 and 52 3 grams respect vely Wh le Malayattur recorded a slight increase over the above mentioned provenances The highest 100 seed weight of 79 85 g was in favour of Parambikulam which showed an increase of 27 5 g per 100 fru ts over the lowest value of local provenance

4 1 3 Purity percentage

The lowest purity percentage value was recorded n the case of local provenance (75 82) wh ch was significantly inferior to all other seed sources (Table 4) Maximum value was exhibited by Parambikulam (86 96) closely followed by Wynad and N lambur 86 10 and 86 01 respectively

4 1 4 Individual seed characteristics

Seed length seed w dth th ckness and seed weight was the max mum for Paramb kulam which was significantly superior to all other provenances tested (Table 5) The lowest seed length width and thickness was observed in Malayattur provenance wh le the least seed weight was exh bited by local provenance

4 2 Germination characteristics

The data obta ned on germ nat on of seeds from different provenances of teak are presented in Tables 6 and 7

Table 5 Variation in individual seed parameters of teak provenances

Provenance	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	Seed weight (g)
Konni	14 59	13 77	12 43	0 545
Arienkavu	14 46	13 36	12 29	0 681
Malayattur	43 28	12 62	10 98	0 585
Thrissur	43 84	14 14	11 52	0 521
Wynad	13 94	13 35	12 63	0 626
Nilambur	15 29	14 44	12 47	0 659
Parambikulam	16 44	15 59	13 25	0 809
F	**	**	**	**
CD (0 05)	0 806	0 767	0 693	0 039
SEM(±)	0 290	0 277	0 250	0 014
CV (%)	9 99	10 07	10 23	11 35

4.2.1 Germination in Laboratory

Days taken to complete germination was insignificant in the case of provenances tested. However, Parambikulam (31 days) performed slightly better than other provenances. Local provenance recorded the longest period of 37 days (Table 6).

Provenances showed a high significant difference in germination percentage with maximum value associated with Konni (76%). The least percentage of germination was exhibited by Malayattur (50%) and Wynad with 54% which were significantly inferior to others.

Peak value of germination for seeds collected from different provenances were found to be significantly different. Peak value increased in the order of Malayattur < Wynad < Thrissur < Arienkavu < Parambikulam < Nilambur < Konni.

Mean daily germination (MDG) also showed a similar trend of peak value for germination. However, seeds from Konni recorded the highest (2.28) closely followed by Nilambur (2.09). Malayattur provenance recorded the least MDG of 1.53 compared to others tested.

4.2.2 Germination in nursery

Germination behaviour of seeds in the nursery were not significantly influenced by the provenance variation (Table 7).

Table 6 Germination behaviour of teak provenances in the laboratory

Provenance	Days taken to complete germination	Germination percentage	Germination value	Peak value	Mean daily germination
Konni	33 5	76	7 22	3 15	2 28
Arienkavu	35 5	62	5 39	2 76	1 89
Malayattur	32 7	50	3 22	2 10	1 53
Thrissur	37 2	64	4 44	2 55	1 71
Wynad	33 5	54	3 79	2 20	1 65
Nilambur	34 2	71	6 23	2 93	2 09
Parambikulam	31 0	59	5 34	2 78	1 91
F	NS	**	**	**	*
CD (0 05)		7 756	2 213	0 649	0 792
SEM(±)		2 636	0 752	0 220	0 269
CV (%)		8 47	4 73	16 73	15 46

Table 7 Germination behaviour of seeds of seven teak provenances in the field

Provenance	Days taken to complete germination	Germination percentage	Germination value	Peak value	Mean daily germination
Konni	37 0	76 1	7 58	3 66	2 05
Arienkavu	34 6	67 9	6 01	3 04	1 96
Malayattur	34 6	55 7	4 28	2 61	1 54
Thrissur	35 6	64 3	5 38	2 95	1 74
Wynad	33 0	58 1	4 90	2 67	1 73
Nilambur	36 0	72 6	6 81	3 32	1 96
Parambikulam	32 6	60 8	5 76	3 03	1 83
F	NS	NS	NS	NS	NS
CD (0 05)					
SEM(±)	2 015	5 693	0 883	0 240	0 155
CV (%)	10 03	15 15	26 28	13 68	17 01

In the case of days taken to complete germination Parambikulam recorded the shortest period of 32 6 days The longest period was taken by Konni (37 days) closely followed by Nilambur with 36 days

Germination percentage and germination value were found to be the highest in Konni provenance (76 1% and 7 58) while the least was in Malayattur (55 7% and 4 28 respectively)

Mean daily germination was in the order of Konni > Nilambur and Arienkavu > Parambikulam > Thrissur > Wynad > Malayattur

4 3 Biometric observations

The results of the biometric observation on teak seedlings of different provenances at different intervals of time are presented in Table 8 to 15

4 3 1 Shoot height

A highly significant variation (P > 0 0001) was observed at 60 DAS 240 DAS and 360 DAS among the provenances in respect to shoot height (Table 8) Upto 240 DAS Konni recorded the highest rate of growth in height later replaced by Parambikulam Nilambur and Malayattur Local provenance exhibited the lowest rate at later stages being slightly superior than Malayattur at 60 DAS and 180 DAS Arienkavu was almost on par with Wynad through out the growth stages

Table 8 Shoot height (cm) of seedlings of seven teak provenances

Provenance	Days after sow ng					
	60	120	180	240	300	360
Konni	21 02	38 61	40 34	42 26	66 33	77 01
Arienkavu	17 25	33 86	35 45	37 40	55 71	65 67
Malayattur	16 13	29 05	31 76	41 32	62 58	82 63
Thrissur	16 38	33 95	35 08	36 77	51 54	62 18
Wynad	13 85	31 74	33 31	35 16	57 17	67 97
Nilambur	15 66	35 75	38 90	49 57	59 44	88 24
Parambikulam	16 96	37 54	38 94	49 35	58 58	90 18
F	**	NS	**	*	NS	*
CD (0 05)	3 350		4 488	4 554		8 078
SEM(±)	1 209	2 331	1 619	1 643	3 221	2 914
CV (%)	21 65	20 35	13 40	11 82	16 44	11 44

4 3 2 Collar diameter

As regards to rad al growth seedlings of Nilambur and Parambikulam registered a high significant values at 240 300 and 360 days after sowing (Table 9) Local provenance consistently registered the lower values for collar diameter growth at all stages of exper mental period Wynad showed a s m lar trend w th Ar enkavu provenance

4 3 3 Leaf production of seedlings

On 60 240 300 and 360 days after sow ng the differences were highly sign f cant in respect of leaf number per plant Parambikulam and Nilambur recorded the maximum number of leaves than any other provenances at 240 300 and 360 DAS (Table 10) Konni which recorded the highest value during initial stages showed a decrease n 180 DAS and found improv ng subsequently to reach closer to Parambikulam Nilambur and Malayattur at the later stages Thrissur reg stered higher number of leaves at 240 DAS but the number of leaves was found to decrease dur ng the final stages

4 3 4 Leaf area

Leaf area per plant showed a sign f cant var ation (Table 11) at the shedd ng period (240 DAS) and after e 300 and 360 respectively Paramb kulam N lambur and Malayattur provenances were s gnificantly superior to all others tested on these per od Local provenance incidentally produced the least amount of leaf area being sl ghtly super or to Malayattur at the initial stages upto 240 DAS

Table 9 Collar diameter (mm) of seedlings of seven teak provenances

Provenance	Days after sowing					
	60	120	180	240	300	360
Konni	5 78	10 12	10 21	10 36	16 14	21 99
Arienkavu	5 56	9 39	9 87	10 35	14 41	19 88
Malayattur	4 89	9 25	9 54	9 84	16 64	26 52
Thrissur	4 83	9 16	9 27	9 59	12 06	17 99
Wynad	5 12	9 54	9 96	10 35	14 68	20 29
Nilambur	4 94	10 24	11 20	12 18	18 97	26 87
Parambikulam	5 30	10 12	10 43	11 81	19 19	26 78
F	NS	NS	NS	**	**	**
CD (0 05)				1 309	1 864	1 823
SEM(±)	0 417	0 437	0 469	0 472	0 672	0 657
CV (%)	24 05	13 55	13 99	13 42	13 46	8 61

Table 10 Number of leaves per plant of seven teak provenances at various stages of growth

Provenance	Days after sowing					
	60	120	180	240	300	360
Konni	13 88	11 44	5 11	4 44	6 66	8 66
Ar enkavu	13 66	10 77	5 55	4 77	6 77	8 44
Malayattur	13 00	9 33	5 66	4 33	6 60	9 68
Thr ssur	11 44	11 11	6 22	4 33	5 77	7 33
Wynad	12 22	10 55	5 88	4 11	6 33	8 00
N lambur	12 11	10 11	5 88	5 33	7 44	9 65
Paramb kulam	12 77	10 22	5 33	5 11	7 66	9 77
F	*	NS	NS	*	**	**
CD (0 05)	1 521			0 650	0 909	0 896
SEM(±)	0 548	0 564	0 331	0 234	0 327	0 323
CV (%)	12 93	16 11	17 57	15 20	14 76	14 42

Table 11 Leaf area (cm^2) of seedlings of seven teak provenances

Provenance	Days after sowing					
	60	120	180	240	300	360
Konni	378 44	1088 30	1158 31	522 36	2253 34	2979 61
Arienkavu	306 31	1025 33	1069 25	585 83	1613 54	2937 90
Malayattur	219 62	819 22	918 22	724 30	2910 06	3935 48
Thr ssur	223 24	891 54	976 82	445 93	1228 03	2003 96
Wynad	289 54	967 71	1063 53	439 91	2343 40	2482 05
N lambur	280 94	1115 91	1224 91	721 43	2944 63	4428 39
Parambikulam	295 62	1148 22	1338 94	678 94	3456 77	4663 64
F	NS	NS	NS	*	*	
CD (0 05)				208 93	574 96	929 40
SEM(±)	50 11	49 51	129 89	75 375	185 84	335 30
CV (%)	52 92	35 57	35 20	28 43	20 17	18 92

4.3.5 Root length

A highly significant variation (P value < 0.0001) in root length was observed among provenances except at 120 and 300 DAS. Parambikulam and Nilambur registered the maximum root length at 180, 240 and 360 DAS. Malayattur was on par with these provenances at 360 DAS (Table 12). Konni recorded the maximum root length at 60 DAS but declined subsequently. Wynad recorded the least at 60 and 240 DAS, while at 180 DAS the minimum root length was noted in Malayattur. Local provenance showed an intermediate performance at initial stages but was minimum at 360 DAS.

4.3.6 Number of lateral roots per plant

Provenance variation had not showed any significant effect on the number of lateral roots produced per seedling. However, Konni showed an increased number of root lets at most of the stages (240, 300 and 360 DAS). At all stages of observations local provenance exhibited the least values (Table 13).

4.3.7 Number of fresh lateral roots per plant

The number of physiologically active lateral roots per plant (white in colour) showed significant variation except at 120 and 300 DAS. Malayattur, Nilambur and Parambikulam recorded the maximum number of fresh lateral roots (Table 14). Local seed source showed the least values for most of the stages.

Table 12 Root length (cm) of seedlings of seven teak provenances

Provenance	Days after sowing					
	60	120	180	240	300	360
Konni	24 70	29 13	40 71	43 81	59 64	70 45
Arienkavu	20 47	36 55	38 48	41 04	58 26	68 40
Malayattur	22 11	33 57	34 84	44 91	58 58	79 81
Thrissur	19 60	34 08	41 93	43 91	53 53	62 45
Wynad	16 41	36 08	39 04	41 18	58 37	68 16
Nilambur	19 81	38 42	43 06	53 64	60 27	85 07
Parambikulam	20 67	39 56	42 26	53 46	64 31	85 04
F	**	NS	**	**	NS	**
CD (0 05)	4 127		4 058	4 110		7 317
SEM( )	1 489	1 950	1 464	1 482	2 687	2 639
CV (%)	21 75	15 87	10 97	9 67	13 67	10 67

Table 13 Number of lateral roots of seedlings of seven teak provenances

Provenance	Days after sowing					
	60	120	180	240	300	360
Konni	26 56	35 3	47 8	50 3	52 7	64 8
Arienkavu	25 3	35 7	48 2	49 7	50 1	62 6
Malayattur	25 8	34 4	47 1	48 8	51 4	63 2
Thrissur	25 1	33 2	45 4	45 2	45 8	57 4
Wynad	27 4	36 9	47 4	49 6	52 5	64 4
Nilambur	26 8	36 7	47 9	48 5	52 0	64 2
Parambikulam	26 2	37 1	48 1	48 8	49 5	62 2
F	NS	NS	NS	NS	NS	NS
CD (0 05)						
SEM(±)	1 503	3 026	3 273	3 003	3 286	2 661
CV (%)	17 21	17 94	15 66	10 87	12 89	9 22

Table 14 Number of fresh lateral roots of seedlings of seven teak provenances

Provenance	Days after sowing					
	60	120	180	240	300	360
Konni	4 77	5 33	6 77	5 11	7 11	7 22
Arienkavu	4 66	5 22	6 66	5 00	7 11	7 33
Malayattur	5 41	5 44	8 77	6 11	7 22	7 44
Thrissur	4 44	5 00	6 77	4 88	7 22	7 22
Wynad	4 77	5 55	6 77	5 33	7 22	7 55
Nilambur	6 00	5 88	8 00	6 00	8 22	8 55
Parambikulam	5 77	5 77	7 66	6 00	8 00	8 39
F	**	NS	**	*	NS	**
CD (0 05)	0 668		0 722	0 073		0 830
SEM(±)	0 241	0 104	0 260	0 263	0 2092	0 299
CV (%)	14 26	12 35	11 07	14 79	12 46	11 75

4 3 8 Populatıon characterıstıcs

Seedlıng populatıon dıd not show marked varıabılıty among the provenances (Table 15) In the case of survıval percentage local provenance showed comparatıvely hıgher values whıle the mınımum was noted ın Wynad

4 4 Bıomass characterıstıcs

The results obtaıned on the bıomass character st cs of the seedlıngs of dıfferent provenances are presented ın Tables 16 23

4 4 1 Stem dry weıght

Seedlıngs of dıfferent provenances showed hıghly sıgn f cant var atıon wıth respect to stem dry weıght especıally at the later stages of observatıons (240 300 and 360 DAS) Parambıkulam Nılambur and Malayattur reg stered the maxımum values (Table 16) whıle the mınımum at 240 DAS was assocıated wıth Wynad Local provenance was characterızed by relatıvely low accumulatıon rate at 300 and 360 DAS

4 4 2 Leaf dry weıght

Table 17 showıng the leaf dry weıght dıd not d ffer sıgnıf cantly among the provenances except at 360 DAS Parambıkulam produced the maxımum dry weıght whıle N lambur and Malayattur and Konnı were comparable n thıs respect The mın mum dry we ght was recorded ın the local provenance

Table 15 Population growth characteristics of seven provenances of teak

Provenance	Number of plants at initial stage	Number of plants at final stage	Survival per cent (%)
Konni	458 0	436 0	95 22
Arienkavu	407 6	380 6	93 18
Malayattur	334 6	313 0	93 23
Thrissur	385 6	368 3	95 31
Wynad	349 0	318 3	90 71
Nilambur	436 0	410 6	94 09
Parambikulam	365 3	338 3	92 42
F	NS	NS	NS
CD (0 05)			
SEM( )	34 392	35 442	1 113
CV (%)	15 24	16 75	2 06

Table 16 Stem dry weight (g plant) of seedlings of seven teak provenances

Provenance	Days after sowing					
	60	120	180	240	300	360
Konni	1 076	2 751	3 446	3 973	9 752	16 043
Arienkavu	0 920	3 306	4 128	4 671	8 153	13 300
Malayattur	0 541	3 145	3 653	7 172	10 288	25 441
Thrissur	0 578	3 685	4 441	4 941	6 386	11 056
Wynad	0 697	3 204	3 644	4 210	8 420	13 916
Nilambur	0 808	4 435	5 587	8 813	14 868	25 937
Parambikulam	0 784	4 621	4 499	8 079	14 956	26 135
F	NS	NS	NS	**	**	*
CD (0 05)				1 309	4 494	4 506
SEM(±)	0 169	0 494	0 562	0 472	1 621	1 625
CV (%)	65 93	42 33	40 18	23 70	26 44	25 91

Table 17 Leaf dry weight (g plant) of seedlings of seven teak provenances

Provenance	Days after sow ng					
	60	120	180	240	300	360
Konn	1 710	6 517	6 872	3 099	9 553	13 432
Arienkavu	1 442	5 788	6 195	3 397	7 129	11 914
Malayattur	0 981	4 977	5 869	2 812	10 103	14 395
Thr ssur	1 105	5 023	5 391	2 393	5 955	9 825
Wynad	1 094	5 702	6 106	3 482	8 573	12 811
Nilambur	1 008	6 379	6 182	3 968	10 274	14 711
Parambikulam	1 214	6 831	7 179	3 639	12 724	17 237
F	NS	NS	NS	NS	NS	*
CD (0 05)						4 309
SEM( )	0 216	0 717	0 769	0 402	1 520	1 554
CV (%)	53 24	36 57	36 89	37 12	49 64	23 17

4 4 3 Specific leaf area

During the final stages that is from 240 DAS onwards significant variations were seen with respect to specific leaf area (Table 18) Nilambur Parambikulam and Malayattur registered the maximum specific leaf area and were significantly superior to others tested Wynad recorded the minimum at 240 and 360 DAS while local provenance exhibited the least amount of specific leaf area at 300 DAS

4 4 4 Shoot dry weight

With respect to shoot dry weight none of the provenances showed significant variation at initial stages (Table 19) The observations taken at 240 300 and 360 DAS showed that Parambikulam Nilambur and Malayattur were significantly superior to others Local provenance consistently recorded the least shoot dry weight

4 4 5 Root dry weight

Significant variations were observed in respect of root dry weight of seedlings at 240 and 360 DAS as shown in Table 20 The highest mean values were attained by Parambikulam Nilambur and Malayattur and were significantly superior to other provenances tested Local provenance showed the minimum root dry weight

4 4 6 Root Shoot ratio

Regarding the root shoot ratio provenances did not show any significant difference at any of the period (Table 21)

Table 18 Specific leaf area (cm^2 g) of seedlings of seven teak provenances

Provenance	Days after sowing					
	60	120	180	240	300	360
Konni	227 18	172 63	166 22	168 55	255 70	221 75
Arienkavu	229 66	177 28	175 23	172 44	227 74	221 21
Malayattur	231 34	165 46	165 74	186 57	288 03	273 39
Thrissur	204 81	183 48	191 13	159 41	206 55	204 25
Wynad	254 79	173 84	205 17	126 33	253 85	193 74
Nilambur	321 42	178 41	212 46	181 83	291 96	280 91
Parambikulam	246 90	167 59	192 60	186 55	271 62	270 71
F	NS	NS	NS	**	**	**
CD (0 05)				6 074	31 720	29 496
SEM(±)	24 710	7 732	22 635	2 191	11 768	10 643
CV (%)	30 24	13 23	36 32	3 64	14 06	12 83

Table 19 Shoot dry weight (g plant) of seedlings of different teak provenances

Provenance	Days after sowing					
	60	120	180	240	300	360
Konni	2 841	9 268	10 318	7 073	18 305	29 476
Arienkavu	2 311	9 094	10 323	8 069	15 282	25 213
Malayattur	1 522	8 122	9 521	9 984	24 391	39 806
Thrissur	1 682	8 077	9 832	7 334	12 344	20 881
Wynad	1 791	8 906	9 750	7 692	16 993	26 727
Nilambur	1 817	10 814	11 767	12 781	24 842	40 648
Paramb kulam	1 999	10 852	11 678	11 807	27 480	43 373
F	NS	NS	NS	**	**	*
CD (0 05)				1 728	6 353	6 534
SEM( )	0 373	1 104	0 893	0 623	2 292	2 357
CV (%)	56 24	35 27	25 64	20 28	24 97	21 89

Table 20 Root dry weight (g plant) of seedlings of seven teak provenances

Provenance	Days after sowing					
	60	120	180	240	300	360
Konni	1 281	4 024	4 740	5 360	18 244	23 996
Arienkavu	1 138	4 196	6 132	6 768	14 604	20 456
Malayattur	0 708	3 871	4 359	8 611	15 642	29 068
Thrissur	0 732	4 613	5 272	6 193	15 228	20 203
Wynad	0 849	4 556	5 304	5 985	15 633	21 525
Nilambur	1 131	5 482	5 911	9 890	18 784	30 230
Parambikulam	0 937	4 897	5 398	9 132	19 196	30 972
F	NS	NS	NS	*	NS	**
CD (0 05)				1 424		4 699
SEM(±)	0 183	0 493	0 515	0 514	1 674	1 695
CV (%)	56 72	32 74	29 16	21 02	29 97	20 18

Table 21 Root shoot ratio of seedlings of different teak provenances

Provenance	Days after sowing					
	60	120	180	240	300	360
Konni	0 459	0 500	0 497	0 757	1 103	0 869
Arienkavu	0 620	0 463	0 620	0 901	0 982	0 816
Malayattur	0 472	0 476	0 473	0 809	0 798	0 722
Thrissur	0 456	0 517	0 569	0 869	1 452	1 017
Wynad	0 449	0 545	0 557	0 857	0 950	0 813
Nilambur	0 659	0 542	0 511	0 782	0 838	0 735
Parambikulam	0 482	0 466	0 464	0 786	0 807	0 717
F	NS	NS	NS	NS	NS	NS
CD (0 05)						
SEM(±)	0 077	0 048	0 060	0 426	0 166	0 085
CV (%)	44 95	29 07	34 51	105 36	50 51	31 44

4 4 7 Relatıve growth rate

Table 22 shows the relatıve growth rate of provenances at dıfferent stages of growth Only durıng the leaf shedd ng tıme (240 DAS) the mean RGR values were found to be s gnıf cantly d fferent Nılambur recorded the max mum at that t rr e and the least was showed by Konn The relatıve growth rates were not pronounced at other stages of growth

4 4 8 Net assımılatıon rate

The mean values of net assımılatıon rate for the provenances showed s gnıfıcant varıatıons at 240 and 360 DAS (Table 23) Nılambur reg stered the maxımum value at 240 DAS replaced by Malayattur at 360 DAS The lowest values of NAR at 240 and 360 DAS showed by Konnı and Wynad respect vely

4 5 Physıologıcal characterıstıcs

Observatıons based on varıous physıolog cal parameters of dıfferent teak provenances are presented ın Tables 24 to 28

4 5 1 Leaf dıffusıve resıstance

The data on leaf dıffusıve resıstance recorded durıng the exper mental per od are presented ın Table 24 The mean values of LDR recorded at mıd day showed s gnıfıcant varıatıon among the provenances through out the perıod Parambıkulam showed the hıghest values at 60 180 and 300 DAS whıle Konnı and N lambur reg stered the max mum at 120 and 240 DAS respectıvely At 360 DAS the max mum

Table 22 Relatıve growth rate (g g^{1} week x 10^{2}) of seedlıngs of dıfferent teak provenances

Provenance	Days after sowıng					
	60	120	180	240	300	360
Konn		14 910	2 576	4 456	11 915	5 844
Ar enkavu		19 306	1 646	3 366	8 028	6 446
Malayattur		22 143	2 474	0 402	9 091	8 152
Thrıssur		20 328	2 024	3 188	5 825	7 200
Wynad		20 452	1 545	3 222	10 016	5 849
N lambur		22 358	1 188	1 417	7 471	7 772
Paramb kulam		21 780	1 121	0 275	9 625	7 274
F		NS	NS	**	NS	NS
CD (0 05)				3 007		
SEM(±)		2 677	0 912	1 085	1 510	0 630
CV (%)		39 79	152 31	192 09	51 18	27 27

Table 23 Net assimilation rate (g g^{1} week x 10) of seedlings of seven teak provenances

Provenance	Days after sowing					
	60	120	180	240	300	360
Konni		12 079	2 733	4 435	13 00	6 217
Arienkavu		15 414	1 622	4 286	10 048	6 341
Malayattur		19 323	2 620	0 398	13 041	8 936
Thr ssur		20 169	1 893	4 118	7 613	7 224
Wynad		16 645	1 184	3 120	9 288	4 892
Nilambur		18 731	1 114	1 080	9 346	8 035
Parambikulam		18 223	1 120	0 091	10 776	6 684
F		NS	NS	**	NS	*
CD (0 05)				3 776		2 234
SEM(±)		2 658	0 955	1 362	0 806	0 806
CV (%)		46 30	163 35	198 81	35 03	25 03

Table 24 Leaf diffusive resistance (cm ^{2} s) of seedlings of seven teak provenances

Provenance	Days after sowing					
	60	120	180	240	300	360
Konni	7 55	13 57	14 23	2 27	2 39	7 66
Arienkavu	5 45	9 01	12 19	2 44	2 29	4 28
Malayattur	4 23	7 70	7 40	2 10	2 64	4 28
Thrissur	4 39	6 47	8 57	2 41	2 43	5 45
Wynad	4 73	6 10	8 96	2 51	3 39	9 29
Nilambur	9 04	12 40	15 72	2 66	2 30	4 40
Parambikulam	9 29	12 68	16 00	2 37	2 71	9 207
F	**	**	**	**	**	*
CD (0 05)	1 378	1 979	2 265	0 201	0 270	1 355
SEM(+)	0 497	0 714	0 817	0 172	0 097	0 489
CV (%)	23 37	22 07	20 66	9 09	11 28	23 04

Table 25 Transpiration rate (μg H_2O cm s) of seedlings of different teak provenances

Provenance	Days after sowing					
	60	120	180	240	300	360
Konni	4 47	2 34	2 38	19 90	16 94	4 89
Arienkavu	5 55	3 56	2 05	19 38	16 66	6 98
Malayattur	6 97	4 52	4 67	19 93	16 30	7 02
Thrissur	6 91	5 37	4 11	18 60	15 17	5 55
Wynad	6 68	5 36	2 78	16 09	10 39	3 20
Nilambur	3 55	2 62	1 97	16 08	16 87	6 92
Parambikulam	3 55	2 62	1 97	16 08	16 87	6 92
F	**	**	**	**	**	**
CD (0 05)	1 041	0 852	0 602	1 921	1 743	1 031
SEM(±)	0 375	0 307	0 217	0 693	0 629	0 372
CV (%)	21 11	24 8	23 01	11 43	12 35	25 12

Table 26 Leaf temperature (°C) of seedlings of different teak provenances

Provenance	Days after sowing					
	60	120	180	240	300	360
Konni	36 77	36 95	35 58	36 46	35 53	30 77
Arienkavu	35 40	36 15	36 18	36 60	35 85	28 13
Malayattur	33 93	35 35	34 12	36 33	36 00	28 06
Thrissur	33 62	35 77	34 63	36 56	34 76	29 40
Wynad	34 14	35 66	34 81	36 60	34 87	31 25
Nilambur	36 61	37 74	36 45	36 05	25 16	27 62
Parambikulam	37 23	38 03	36 47	36 04	35 50	30 77
F	**	NS	**	**	**	**
CD (0 05)	1 644		0 381	0 164	0 255	1 646
SEM(±)	0 593	0 714	0 498	0 059	0 092	0 594
CV (%)	5 03	22 07	4 15	0 49	0 78	5 03

Table 27 Leaf water potential (MPa) of seedlings of seven teak provenances

Provenance	Days after sowing					
	60	120	180	240	300	360
Konni	0 59	0 78	1 57	0 74	0 62	0 60
Arienkavu	0 59	0 89	1 67	0 78	0 66	0 48
Malayattur	0 48	0 80	1 70	0 87	0 73	0 48
Thrissur	0 53	0 78	1 59	0 83	0 76	0 64
Wynad	0 58	0 86	1 55	0 71	0 82	0 64
Nilambur	0 62	0 90	1 72	0 92	0 64	0 53
Parambikulam	0 64	0 93	1 75	0 89	0 76	0 62
F	NS	*	**	**	NS	NS
CD (0 05)		0 109	0 121	0 034		
SEM(±)	0 045	0 039	0 043	0 012	0 057	0 049
CV (%)	23 54	13 86	7 94	4 52	24 13	25 18

values at 120 and 180 DAS and at 240 DAS Nılambur regıstered the maxımum LWP values The lowest values were reported by local provenance at 120 DAS whıle at 180 and 240 DAS Malayattur had the lowest leaf water potent al

4 5 5 Relatıve water content

The relat ve water content of the leaves of seedl ngs of d fferent provenances showed statıstıcally sıgn f cant varıatıon dur ng exper mental perıod The h ghest RWC was recorded at 60 and 360 DAS ın Parambıkulam whereas durıng the rema nıng stages hıgher values of RWC were notıced ın Nılambur (Table 28) At most of the stages the mınımum RWC was characterızed by Konnı wh le at 120 DAS Thrıssur and at 180 and 240 DAS Wynad regıstered the least values

4 6 Anatomıcal observatıons

Stomatal frequency ın the d fferent provenances were hıghly s gn f cant even though the values dıd not show much varıatıon among them (Table 29) Arıenkavu showed the hıghest number of stomates at 60 DAS and durıng the second phase (120 240 DAS) the maxımum number was notıced n Malayattur Konnı regıstered the hıghest number of stomates dur ng the fınal phase of exper mental perıod The m n mum count of stomates was noted ın Paramb kulam at 60 and 120 DAS Wh le the number of stomates was the mın mum ın Konn at 180 and 240 DAS At the fınal phase (300 360 DAS) the mın mum number of stomates was noted ın the Wynad provenance

Table 28 Relative water content (%) of seedlings of seven teak provenances

Provenance	Days after sowing					
	60	120	180	240	300	360
Konni	34 7	46 3	27 8	26 6	32 0	36 2
Arienkavu	47 2	51 8	32 8	30 6	32 0	37 2
Malayattur	36 9	45 4	43 1	42 7	43 7	36 3
Thrissur	40 0	42 4	32 4	30 7	33 3	49 6
Wynad	50 0	45 7	26 4	25 3	34 0	53 7
Nilambur	50 8	53 0	48 1	44 1	48 5	36 2
Parambikulam	54 6	52 9	44 7	41 7	45 2	50 4
F	**	**	**	**	**	**
CD (0 05)	4 572	4 457	10 266	10 336	12 064	11 975
SEM(±)	1 649	1 608	3 705	3 730	4 353	4 321
CV (%)	11 02	10 01	20 47	22 43	23 88	23 17

Table 29 Stomatal frequency (stomates cm ^{2}) of seedlings of different teak provenances

Provenance	Days after sowing					
	60	120	180	240	300	360
Konni	2105	2992	4293	3934	4598	4931
Arienkavu	2382	3075	4792	4432	4155	4543
Malayattur	2355	3518	5291	4820	4155	4543
Thrissur	2382	3324	5041	4543	3961	4294
Wynad	2327	3186	4709	4321	3601	4211
Nilambur	2105	2881	4486	4017	4238	4515
Paramb kulam	1883	2659	4709	4266	3684	4432
F	**	*	**	**	**	
CD (0 05)	195 84	442 65	466 48	460 11	370 63	428 80
SEM(±)	70 63	159 55	168 42	165 92	133 79	154 84
CV (%)	9 48	15 44	10 62	11 47	9 79	11 42

4 7 Variation in nutrient concentration

Concentration of nutrients like Nitrogen Phosphorus and Potass um in d fferent plant parts observed are furn shed n Table 30

4 7 1 Nutrient status on leaves

Concentration of N P and K in the leaves showed a highly sign f cant variation among the provenances tested In the case of N the highest value was registered by Malayattur and was shown to be significantly superior to other provenances (2 621) The least concentration was recorded by local provenance (1 461)

Percentage of phosphorus seemed to be maximum in Malayattur (0 124) wh le the least was associated with Arienkavu (0 088)

With regards to potassium content also Malayattur (0 600) showed the highest concentration Arienkavu provenance incidentally recorded the least in this respect (0 300)

4 7 2 Nutrient content in stem

P and K concentration n the stem of seedlings from various provenances showed highly significant variat on Percentage of P content was the h ghest in Parambikulam (0 049) and the lowest concentration was observed n the local provenance (0 029)

Table 30 Concentration of nutrients (%) in different plant parts of seedlings of seven teak provenance

Provenance	Leaf			Stem			Root		
	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
Konni	1 764	0 116	0 325	0 554	0 041	0 237	0 655	0 047	0 100
Ar enkavu	1 663	0 088	0 300	0 504	0 034	0 250	0 554	0 027	0 087
Malayattur	2 621	0 124	0 600	0 655	0 041	0 325	0 807	0 038	0 125
Thr ssur	1 461	0 097	0 338	0 555	0 029	0 225	0 504	0 033	0 150
Wynad	1 663	0 111	0 563	0 554	0 044	0 175	0 605	0 057	0 100
N lambur	1 865	0 106	0 388	0 655	0 036	0 287	1 109	0 035	0 163
Paramb kulam	1 915	0 099	0 375	0 605	0 049	0 263	0 705	0 033	0 200
F				NS					
CD (0 05)	0 375	0 011	0 061		0 006	0 061	0 178	0 008	0 035
SEM( )	0 1356	0 004	0 0233	0 060	0 002	0 023	0 0646	0 003	0 0123
CV (%)	17 95	9 49	13 96	25 21	15 26	22 66	22 43	22 11	22 86

As regards to K content Malayattur (0 325) exhibited maximum amount of concentration Provenance from Wynad recorded the least amount of K n the stem (0 175)

4 7 3 Nutrient concentration in root

With respect to N concentration the highest value was recorded by Nilambur (1 109) and was significantly superior to others The least concentrat on in this respect was noticed in the local provenance (0 504)

Phosphorus content n roots of Konni provenance was the highest (0 047) and statistically superior to others tested The least was recorded in Arienkavu (0 027)

Parambikulam provenance recorded the h ghest value with respect to K (0 200) and was sign ficantly superior to others tested Wh le Ar enkavu was character zed by low concentration of K n the roots

4 7 4 Variation in the uptake of nutrients

Uptake of nutrients in different plant parts also showed a h ghly sign f cant var ation among provenances (Table 31)

Malayattur exhibited the max mum uptake value in respect of N and K in the leaves while P uptake was h gher in Konni provenance Local provenance cons stently exh bited low N P and K uptake n leaves

Table 31 Uptake of nutrients (g m 2) in different plant parts of seedlings of seven teak provenances

P ovenance	Leaf			Stem			Root		
	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)	N (%)	P (°o)	K (%)
Konn	63 98	4 27	12 24	24 75	1 84	10 40	42 23	3 06	6 69
Ar enkavu	44 50	2 41	8 10	15 76	1 07	7 82	26 33	1 25	5 83
Malayattur	76 25	3 53	17 02	32 61	2 05	15 97	44 18	2 20	6 86
Th ssur	35 83	2 21	7 77	14 82	0 74	5 72	23 75	1 58	6 93
Wynad	41 49	2 77	13 94	15 79	1 19	4 84	26 80	1 61	4 19
N lambur	72 16	4 11	14 82	45 82	2 55	19 28	89 82	2 71	12 78
Paramb kulam	70 48	3 67	14 96	34 27	2 77	14 79	46 36	2 24	12 68
F									
CD (0 05)	27 41	1 44	6 19	16 69	1 04	6 33	23 45	0 78	3 52
SEM(±)	8 89	0 46	2 01	5 41	0 33	2 05	7 61	0 25	1 14
CV (°o)	26 66	24 73	27 42	25 74	23 44	21 63	29 82	20 97	24 76

As regards to the nitrogen and potassium content in the stem the highest values were observed in Nilambur while maximum amount of phosphorus was found in Paramb kulam provenance Thrissur again recorded the least value of uptake n N and P whereas K seemed to be m n mum n Wynad

Nilambur recorded a high magnitude of uptake in the case of N and K w th respect to roots while P uptake was the maximum in Konn provenance The min mum n trogen content in roots was noticed in Thr ssur provenance while the m n mum P content in roots were noticed in Arienkavu Wynad provenance showed the least K content among the provenances

4 7 4 1 Variation in total uptake of nutrients

Total uptake of nutr ents in seedlings of var ous provenances also showed h ghly s gn f cant var ations among them (Table 32)

The maximum uptake with respect to N P and K were observed in N lambur while local provenance consistently registered the least values for the above mentioned nutrients

4 8 Root growth potential

The results of the root growth potential of stumps of the var ous provenances are given in Table 33

The number of sprouts produced from the stumps was not seemed to be sign f cant among the provenances

Table 32 Total uptake of nutrıents N P and K from the soıl (g m ^{2}) by the seedlıngs of seven teak provenances

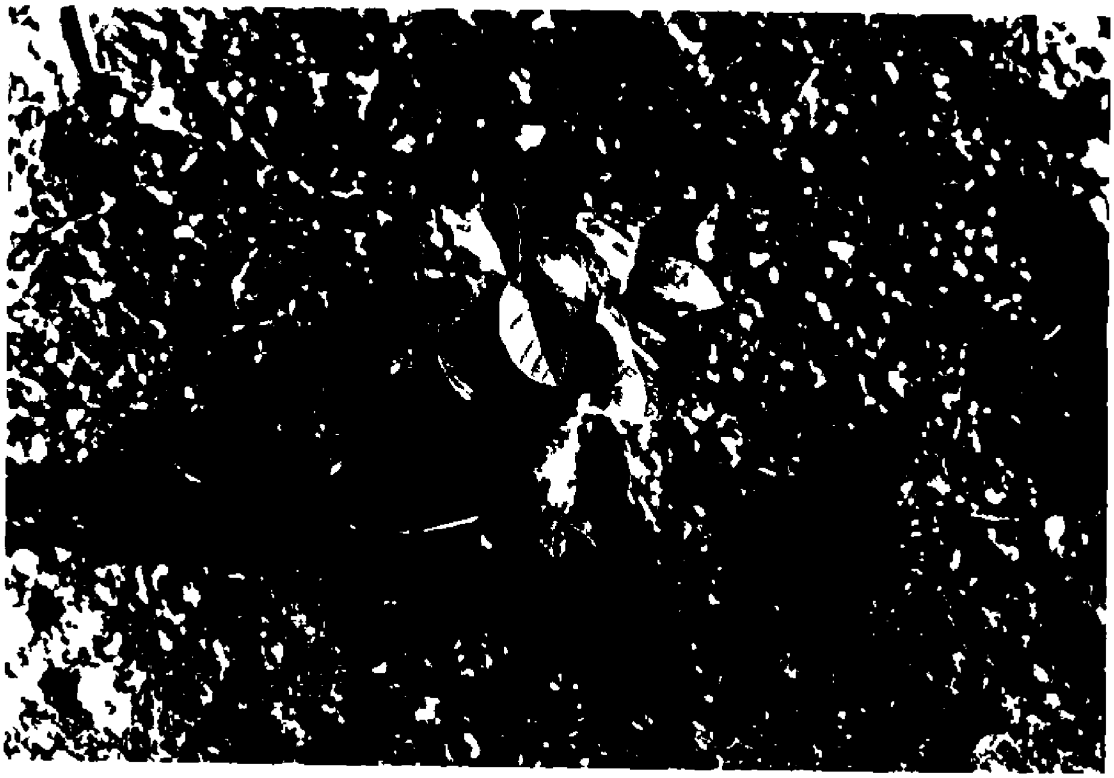
Provenance	Total N	Total P	Total K
Konn	130 97	9 18	29 33
Ar enkavu	86 60	4 74	21 76
Malayattur	153 04	7 78	39 86
Thrıssur	74 41	4 53	20 44
Wynad	84 10	5 58	22 99
Nılambur	207 80	9 37	46 89
Parambıkulam	151 12	8 69	42 44
F	**	*	**
CD (0 05)	50 73	2 64	13 10
SEM(±)	16 46	0 85	4 25
CV (%)	22 48	20 88	23 05

Table 33 Provenance variability on growth behaviour of stumps of different teak provenances

Provenance	Sprouts per stump	Lateral roots per stump	Tertiary roots per stump	Dry weight of lateral roots (g stump)	Length of three largest lateral roots per stump (cms)		
					I	II	III
Konni	2 55	9 77	166 4	0 070	14 68	11 14	ᶜ 76
Arienkavu	2 55	6 66	123 0	0 058	14 08	ᵅ 82	8 18
Malayattur	2 66	13 77	255 0	0 071	17 83	14 03	13 21
Thrissur	2 11	6 00	106 3	0 046	13 72	9 88	8 24
Wynad	3 88	7 00	146 8	0 062	13 84	11 22	10 61
Nilambur	3 44	13 22	201 2	0 129	16 86	15 54	13 97
Parambikulam	2 66	9 00	153 6	0 088	18 85	13 05	10 08
F	NS	**	*		NS		*
CD (0 05)		3 287	86 878	0 041		3 970	3 037
SEM( )	0 500	1 186	31 343	0 015	1 773	1 4326	1 095
CV (%)	62 87	28 06	27 11	28 97	33 88	25 51	20 89

Plate No 5   Teak "stump prepared from one year old seedling

Plate No 6   Sprouted teak stumps   after two weeks of plant ng



The number of fresh lateral roots produced per stump showed a high significant variation among provenances Malayattur and Nilambur were comparable in this respect and was statistically superior to others However local provenance recorded the lowest number of later roots produced per stump

As regards to total number of tertiary roots the differences were significant and were in the order of Malayattur > Nilambur > Konni > Parambikulam > Wynad > Arienkavu > Thrissur

The dry weight of lateral roots recorded was found to be significant among various provenances tested Nilambur was characterized by relatively higher amount of dry matter accumulation while local provenance registered the least value in this respect

As regards to the length of three largest lateral roots per stump statistically significant difference was observed in 2nd and 3rd roots Nilambur and Malayattur were comparable in this respect and were significantly superior to others Arienkavu consistently recorded the least value for root length

4 9 Field establishment

Statistically significant variation was observed in the number of sprouts per stump among the tested provenances of teak (Table 34)

Maximum number of sprouts per stump was produced by Nilambur and Parambikulam while the least number produced by local provenance

Table 34 Provenance variability with respect to the number of sprouts per stump in the field

Provenance	Sprouts per stump
Konni	2 8
Arienkavu	2 5
Malayattur	3 1
Thrissur	2 2
Wynad	3 1
Nilambur	4 0
Parambikulam	3 7
F	**
CD (0 05)	0 4132
SEM(±)	0 1491
CV (%)	22 41

Discussion

DISCUSSION

In most of the characteristics studied significant differences among provenances were observed This means there exists considerable genetic diversity among provenances Most of the provenances have been found to be highly adapted to their habitats

Seed characters

The provenances differed significantly with respect to number of seeds per kg 100 seed weight purity percentage and individual seed characteristics The highest seed weight was noticed in Parambikulam while the least was observed in seeds collected from Malayattur region Environmental influences during the development of seeds with genetic variability can results in variations in seed dimensions according to Willan (1985) The higher seed weight could be attributed to better differential seed filling based on locality or site factors Similar results have been observed in teak by Dabral (1976)

Gupta and Pattanath (1976) reported that the fertility of the site could improve the purity of seeds Banik (1977) suggested that bigger fruits with higher seed weight were found to have low degree of emptiness leading to higher rate of purity percentage In this context Parambikulam exhibited a high rate of purity percentage and higher seed weight

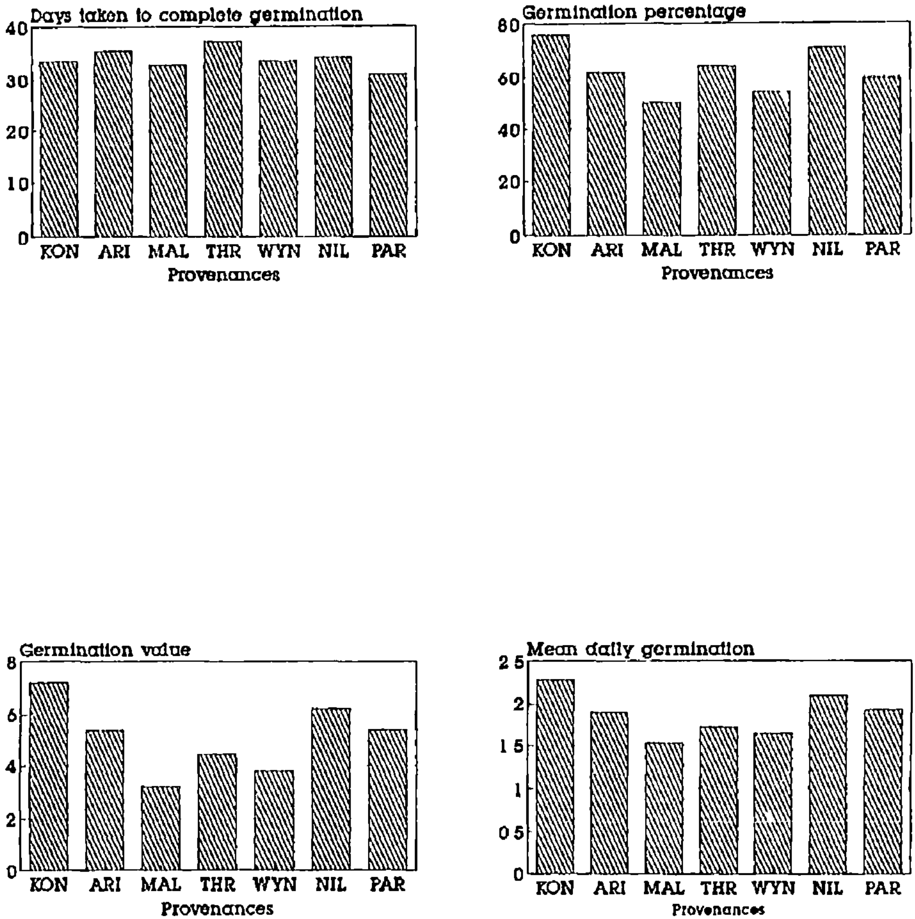
Individual seed characteristics like seed length breadth thickness and weight were the highest in seeds collected from Parambikulam They were the lowest in

Malayattur and Thrissur provenances Generally larger seeds have greater advantage over smaller sized seeds Toon *et al* (1990) have reported that bigger seed size indicates better quality of the seeds and genetic potentialities

Germination characteristics

Under laboratory conditions the provenances studied revealed significant differences with respect to days taken to complete germination germination percentage peak value and mean daily germination (Fig 4) The seeds collected from Parambikulam took about 31 days for completion of germination while seeds from Thrissur took 37 days for completing germination Rest of the provenances were intermediate in performance The seeds of all provenances was subjected to alternate wetting and drying for seven days before sowing This treatment is recommended for higher germination presumably because of the presence of water soluble inhibitors Early germination in the case of Parambikulam could be attributed to quick removal of the inhibitor which might have resulted in early germination Similar results have been observed by earlier workers Kumar (1979) and Bedell (1989) However in the case of germination percentage peak value and MDG were the highest in Konn which recorded medium seed weight germination percentage peak value and MDG were the least in Malayattur provenance Similar results were obtained in germination percentage and mean daily germination by Bedell (1989) in Andhra Pradesh He found that germination percentage and MDG were the highest in Konn provenance compared to Nilambur Parambikulam and Malayattur These results point to the fact that germination percentage and MGD are governed by genetic factors of the provenances as has been reported by Farmer (1980) and Abrecht (1985)

Fig. 4 Germination behaviour of teak provenances in the laboratory



Under f eld cond t ons provenances d d not show s gn ficant var ation with respect to completion of germination germination percentage peak value and MDG Even though the variations were not significant the seeds collected from Konni showed good results in most of the germination characters Th s also confirms the fact that these characters seem to be under strong genet c control

Biometric observations

With respect to shoot and root length (Fig 5) collar d ameter number of leaves and leaf area the provenances of Paramb kulam Nilambur and Malayattur exhibited superior ty over the rest of the provenances n most of the period of observat ons

Glover (1987) reported that a favourable interaction between provenance and the environment resulted in superior seedl ngs The performance of a provenance at a site depends partly on the site and partly on the seed source So the performance of a g ven provenance in respect of growth especially height growth at a site could be at divergence with the native performance of a given provenance Gopikumar and Aravindakshan (1979) stated the higher N P and K content in seeds will contribute for better height growth of seedlings in the nursery They also showed that nutrient status of the seed have a positive correlation to vigour of seedlings However the contention that provenance with h gher germinat on percentage also have greater potent al for he ght growth (Ngulube 1989) s not supported by the present study

Radial expans on (F g 6) and to some extent he ght also was more dur ng the month of h gh ra nfall (June August) This may be due to the fact that mo sture may

Fig 5 Shoot height and root length of seedlings of seven teak provenances

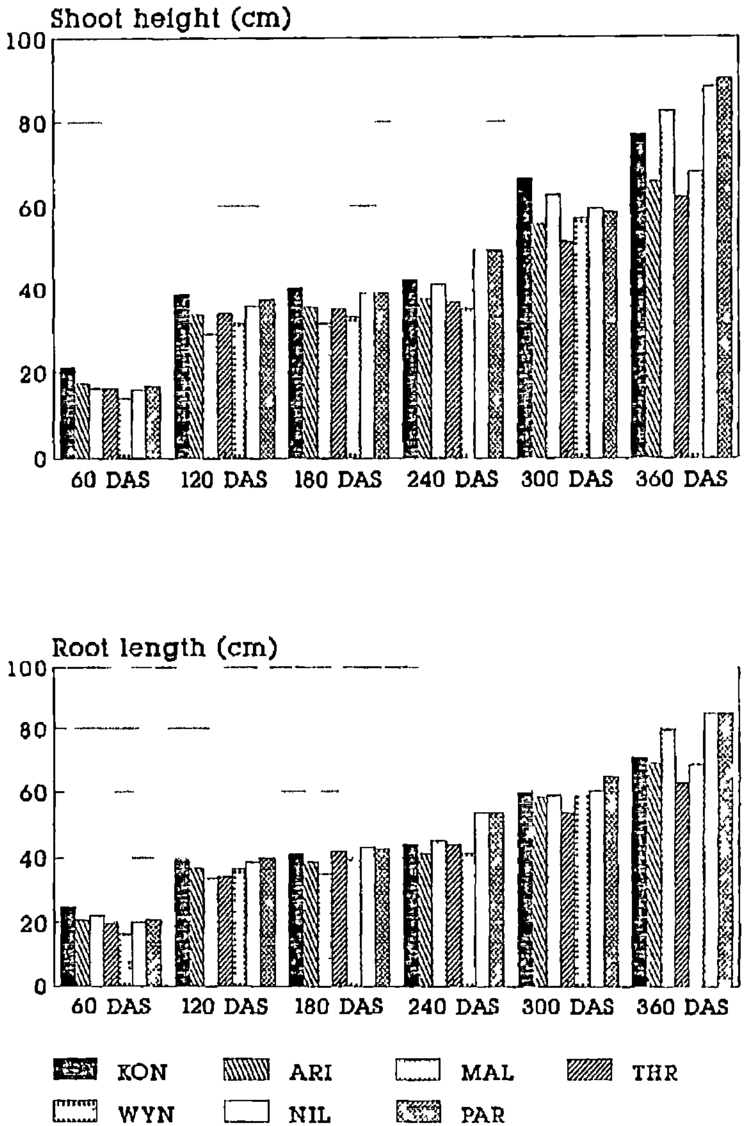
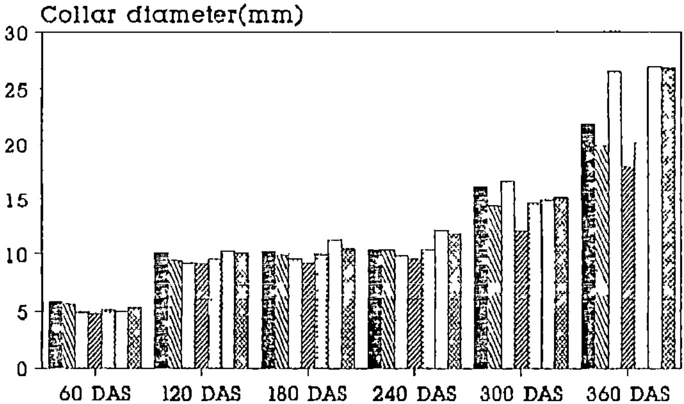


Fig 6 Collar diameter and leaf production of seedlings of seven teak provenances



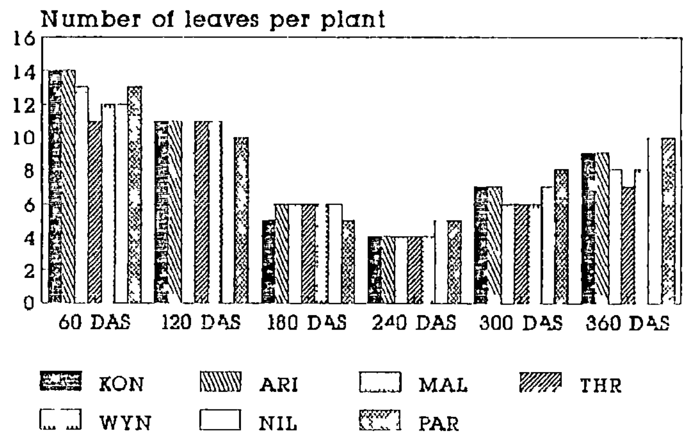
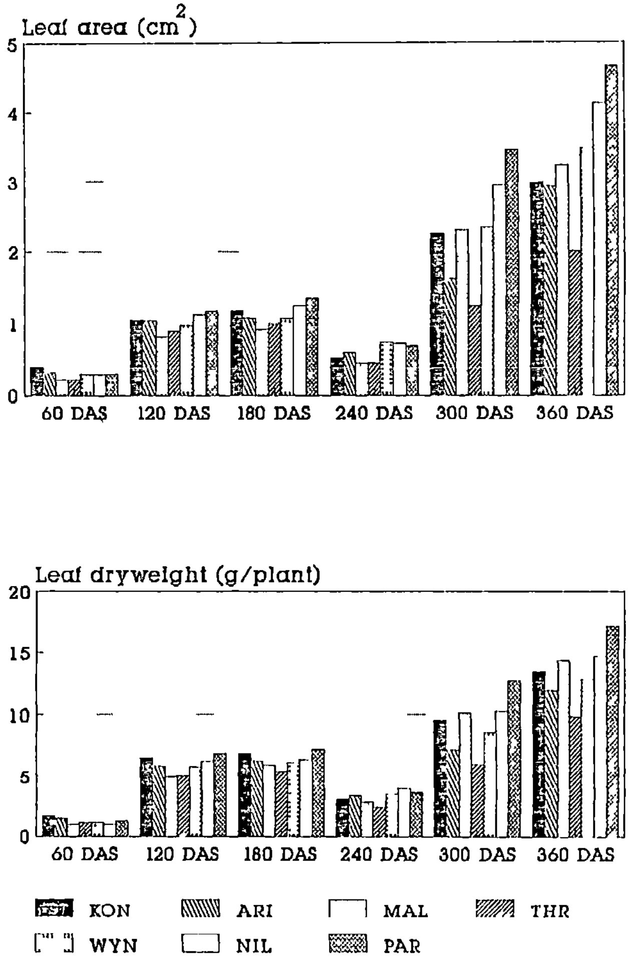


Fig 7 Leaf area and leaf dry weight of seedlings of seven teak provenances



amounts (Goldbold *et al* 1988) In this respect it may be remembered that Konni provenance which showed higher number of lateral roots but lower number of physiologically act ve roots showed relatively lower root length and root dry we ght as compared to other three provenances mentioned above

Regard ng the population characteristics such as mortality and survival of seedlings provenances did not vary significantly

Generally local provenance are well adapted to the climate of the area and the genotype environment interaction will be favourable In the present study also an early advantage at 60 DAS was showed by the local provenance in shoot height root length shoot and root dry weight over the other provenances

Biomass characteristics

With respect to stem root and leaf dry we ght the provenances of Parambikulam N lambur and Malayattur registered the h ghest values espec ally at later stages Similarly RGR and NAR values also were marginally higher in these provenances especially dur ng summer months compared to others

Hazara and Tripathi (1986) reported that biomass production is a funct on of the photosynthetically active radiat on (PAR) fall ng on the leaves The present study also highlights the fact that optimal leaf mass levels would substantially increase the biomass product on It is presumed that the available solar energy was more effect vely used by Parambikulam Nilambur and Malayattur provenances by their leaf number and leaf area

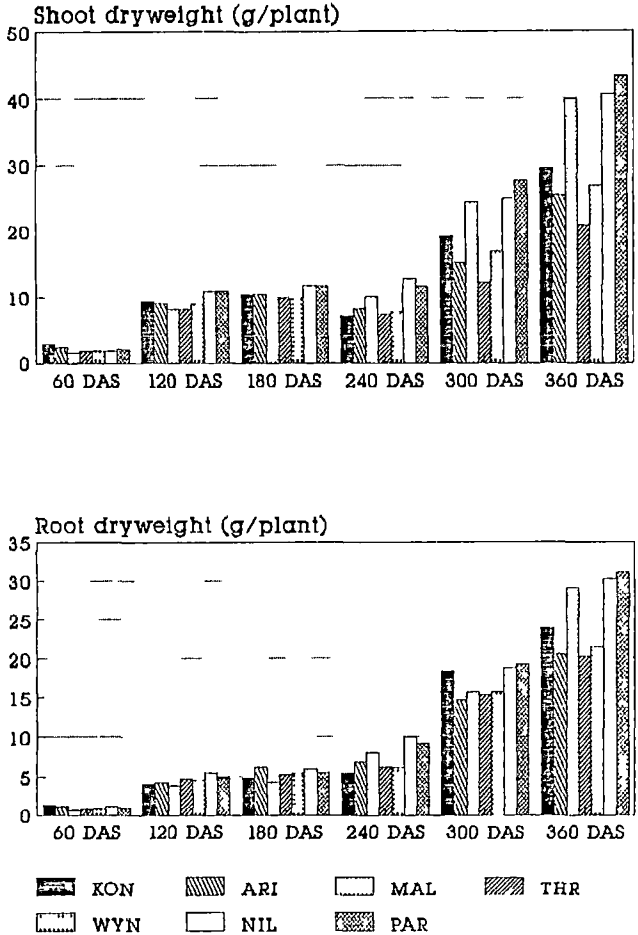
The total dry matter production (Fig 8) decreased considerably in all the provenances during summer due to leaf shedding Water deficit during summer generally have a negative effect on dry matter production in plants as it impairs with many of the physiological processes which determine the growth The reduct on in dry matter production observed would be due to decrease in the number of leaves leaf mass wh ch are posit vely correlated with the total biomass production

Response of the plants in specific leaf area is positively related to water absorpt on (Grier and Running 1977) The reduction n act ve photosynthetic leaf surface is probably the most mportant factor affect ng overall plant growth rate (Watson 1952)

The root shoot weight ratios did not show variation among provenances Generally most of the seedlings allocated approximately equal b omass to aer al shoots and under ground parts According to Parker (1949) equal ratio of root surface to shoot surface found to be better in teak so that water absorption does not become a limiting factor

Relative growth rate (RGR) showed significant difference at peak period of the dry season The plant dry weight of seedlings of the provenances decreased considerably due to shedding of leaves during dry months In Nilambur Parambikulam and Malayattur provenances the decrease in total dry matter was only marg nal This impl es that the negat ve effect of leaf shedding and water stress on RGR of these provenances was neglig ble The leaves ma ntained h gh eff c ency w th respect to dry matter production as indicated by the data on RGR wh ch were relat vely stable as

Fig 8 Variation in shoot and root dry weight of seedlings of seven teak provenances



compared to other provenances It may be remembered that relative growth rate is a function of the dry matter accumulation (Maguire *et al* 1990) Hence it is not surprising that the above three provenances had relatively high shoot dry weight with high relative growth rate

The data on net assimilation rate (NAR) of the various provenances generally points to an increase in efficiency of the available leaf area This concept seems to be true at 240 DAS where the leaf area was the least and the NAR showed a steep decline Under water stress and also at 360 DAS Parambikulam Nilambur and Malayattur showed relatively high significant NAR values indicating the relatively high drymatter production efficiency correlated with available leaf area of provenances

Physiological parameters

In general leaf diffusive resistance (LDR) showed an increasing trend with decreasing water status of the soil (Fig 9) The increase in LDR could be due to severe water deficit situation and the subsequent stomatal closure due to decrease in turgor of guard cells (Kozlowski 1976) The rise in LDR was steeper at the beginning of summer (180 DAS) most of the provenances showed significantly higher LDR The LDR values showed significant drop especially during summer and the fall in LDR was inversely related to the level of transpiration The fact emerging from this data is that leaf production and leaf spread per plant also comes down due to water stress The shedding of the leaves during summer results in decrease of amount of leaf area The transpiration rate of the remaining leaves increases which helps the plant to maintain normal metabolic activities (Cermak 1989) This pattern of leaf shedd ng subsequent fall n leaf area and the increase in the rate of transp rat on was followed by all the provenances

LDR is considered as a d rect indicator of stomatal response of plants and sign ficant rise of LDR of the provenances during summer revealed the pos t ve and strong control of stomates for high water use eff c ency (Pezeshk and Chambers 1985) The LDR in Malayattur d d not show sign ficant increase during waterstress wh ch indicates that in that provenance the stomates were open even in low levels of water status enabling more gas exchange through stomates It appears that the stomates in the provenance could be kept open even during summer possibly because of the production of higher number of physiologically active roots and the subsequent cont nued water supply from the soil (Whitehead 1973) The relatively higher number of active roots in the case of Malayattur dur ng that period (240 DAS) supports this aspect

The elevation of leaf temperature could be chiefly due to the fluctuat ons in transpiration rate caused by the water status of the so l (Idso *et al* 1978) During the peak period of dry cycle (180 240 DAS) a small drop of leaf temperature was observed This may due to the high rate of transpiration in the remaining leaves

Leaf water potential (ψ) is considered as a direct indicator of leaf turgor and hence a good indicator of water status of plants (F g 10) The effect of air temperature on water potential may be explained by d fferent al effects n transp rat on and absorption It can be expected that air temperature would be strongly and pos tively

Fig 9 Leaf diffusive resistance and transpiration rate of seedlings of seven teak provenances

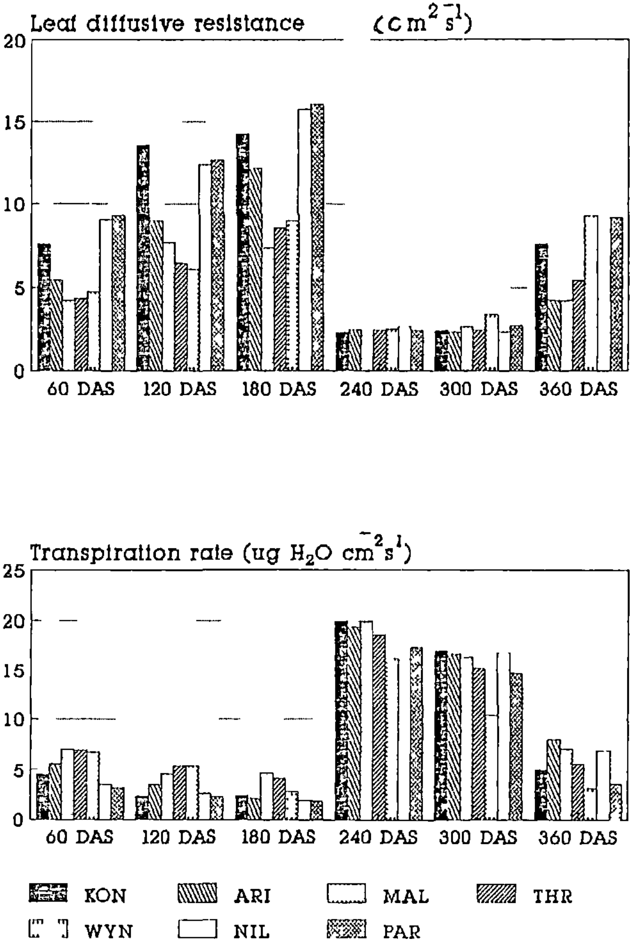
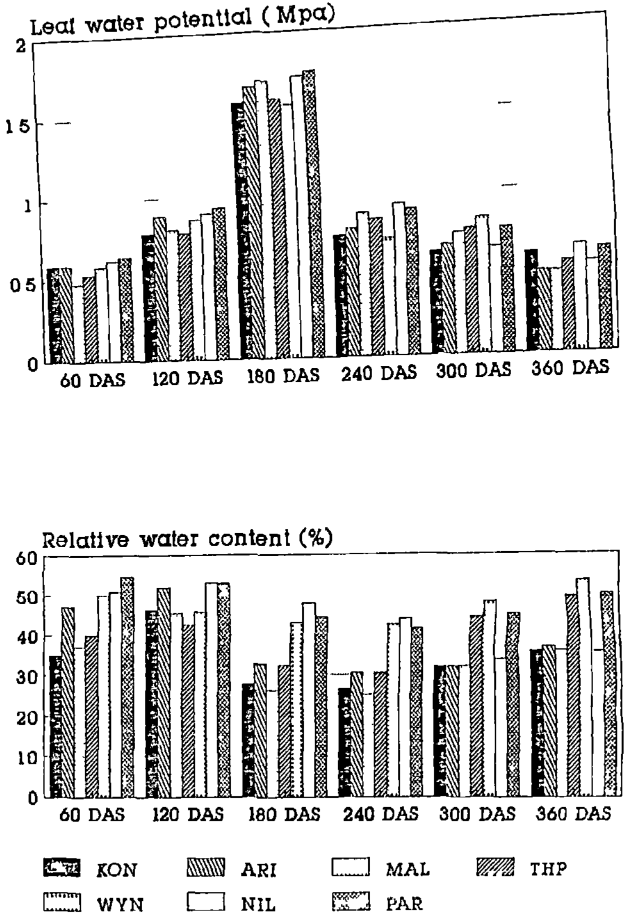


Fig 10 Variation in Leaf water potential and relative water content of seedlings of seven teak provenances



correlated with evaporative demand and hence with transpiration At constant rates of water absorption by the roots water deficit would be expected to increase and the water potential to drop as the air temperature rises Low soil temperature can markedly reduce absorption by roots This might be due to the absence of an elevational gradient in water potential (Teskey *et al* 1984)

A slow decline in the ψ during summer as observed in teak indicates the ability of the plants to withstand water deficit situation In this species leaf turgor was maintained by rapid adjustment of leaf area Generally in all provenances leaf area decreased in response to the arrival of dry spell However water potential showed only marginal decrease When the water status of the soil decreased to moderate and severe levels there was a steep decrease in leaf water potential Parambikulam Nilambur and Malayattur provenances were able to maintain high leaf water potential during the stress periods Higher water potential is related to deeper rooting and also due to the presence of greater amount of fresh active roots in the root zone (Abbssenac and Nour 1986) This is largely attributed to high resistance presented by the xylem vessels in which only the tracheids permitted axial water flow

Eventhough the leaf water potential came down during the dry spell relative water content was not drastically decreased (Fig 10) A rapid decrease in RWC is considered as a character of stress intolerant species (Cowan 1981) Hence a moderate decrease in the RWC during midday indicate that this species was moderately tolerant to water stress The significant values of RWC of Malayattur Parambikulam and Nilambur provenances especially at the dry period indicate the efficiency in maintaining the water status in plants by optimum absorption as suggested by Kozlowski (1982)

Anatomical parameters

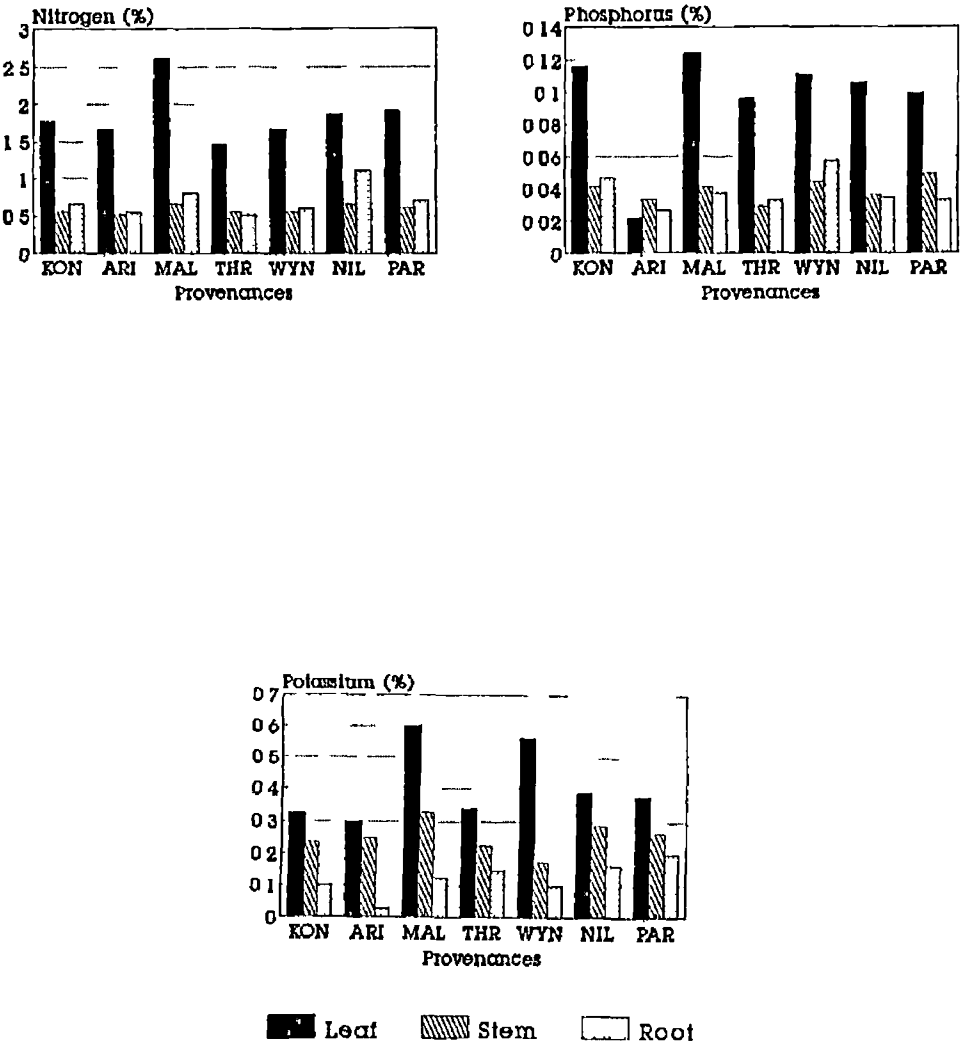
Generally as the water status in the plants decreases plants reduce their water loss by stomatal regulat on mechanism The stomatal frequency was found to be reduced at h gher levels of water stress in the different provenances of teak However a positive correlation between number of stomata and the rate of transpiration was observed in the present experiment Th s is in conf rmation w th the results obta ned by Vandermoezel (1989) Malayattur provenance showed a higher rate of transp rat on throughout the period by its h gher stomatal frequency The rate of transp rat on was lower in the provenances were the stomatal frequency was less

A reduction in the number stomates was observed during peak period of dry spell (180 DAS) in almost all the provenances The reduct on in average leaf size and leaf expansion was associated with the dry cycle The net result was an apparent reduction in the number of stomates (Myers and Landsberg 1989) This rapid adjustment of leaf area is noted n several spec es to maintain the leaf turgur for support ng the water potential grad ents

Nutrient status

The percentage composition of various nutr ents varied considerably among the provenances of teak (Fig 11) The h ghest concentration was generally observed in leaves wh le the stem had the lowest concentrat on of all the nutrients The distr but on of nutrients within the plants was closely associated w th the b olog cal act vity of the plant compartments Any plant part ie root stem and leaves can be cons dered as a

Fig 11 Concentration of nutrients in different plant parts of seedlings of seven teak provenances



source or s nk for the elements especially nitrogen with reference to other plant parts The pattern of concentrations between plant parts are defined as the structure of the nutrient partitioning model (Habib *et al* 1989)

Zech and Dreschsel (1991) reported that teak has a h gh nutrient requirement Def c ency of mineral elements n the soil except potass um has s gn f cantly reduced height growth and dry matter production in teak

Nitrogen concentration varied significantly in leaves and roots of the provenance High amount of nitrogen was observed in Malayattur provenance followed by Parambikulam and Nilambur The high nitrogen content of Malayattur compared to other provenances suggests that an efficient internal cycling of nutrients could have resulted n better growth as was reported by Gurumurthi *et al* (1986) S milarly Adams and Attiwill (1984) suggested that relative abundance of nitrogen in the plant vegetative parts shows the eff ciency of utilizing nitrogen Incidentally nitrogen plays a key role n the metabolism of living cells probably leading to faster cell expansion and cell division which might result in higher vegetative growth rates These assumptions more absolutely favour the above mentioned provenances characterized by higher growth rates Jurik (1986) found a strong positive correlation between leaf mass per plant and net photosynthesis for a variety of hardwood species Greater leaf mass of mature leaves may indicate the presence of more leaf nitrogen to photosynthetic machinery for the assim lat on process This view s supported by the present experimental results

Concentration of phosphorus was found to be highly variable among provenances and did not exhibit a consistent pattern Generally the phosphorus plays an important role in the very large number of enzyme reaction that depend on phosphorylation It appears that the inconsistent pattern of phosphorus concentration in the various plant parts might be due to the masking effect of high accumulation of nitrogen in the various plant parts (Wang *et al* 1991) Although phosphorus was used more efficiently by Konni and Wynad provenances compared to Nilambur and Parambikulam seed sources the biomass accumulation was relatively low which might have been a constraint in the overall productivity It is difficult to screen the provenances based on the P efficiency alone

Potassium content was higher in Malayattur followed by Parambikulam Nilambur and local seed source Potassium has several physiological and biochemical roles for example in protein synthesis (Alan Wild 1988) The productivity of a plant cannot be explained in terms of the concentration of a single nutrient But the efficiency of the utilization of potassium does play a role in productivity The concentration of this nutrient was higher in Malayattur Nilambur and Parambikulam which showed a higher biomass productivity also Potassium use efficiency of the above provenances might have positively contributed to their higher productivity

In essence the uptake of a nutrient is described by the product of concentration of the nutrient in the soil solution and the absorbing capacity of the root and relative growth rate (Alan wild 1989) Data on nutrient uptake indicated the superior capabilities of Malayattur Parambikulam and Nilambur seed sources

Root growth potential

Generally plants with a high root growth potent al (RGP) establish easily and perform well because of their ability to produce new roots promptly after planting (Wakeley 1954) There was a good relationship between RGP and performance of the plant after 3 or 4 weeks (Fig 12)

Shoots per stump d d not showing consistent var at on among the provenances Number of shoots per stump did not have much influence in the biomass production

The number of roots and rootlets produced per stump showed significant var ation among the provenances Nilambur Malayattur and Parambikulam provenance produced higher number of roots and rootlets R tch e (1982) reported that carbohydrates growth regulators or both produced by shoots are necessary for root growth There was a posit ve relat onsh p between stored carbohydrates or photosynthates present in the stumps and the development of healthy root system which resulted in better establ shment It is natural that the stumps with higher amount of reserve food materials performed well in subsequent evaluations (Davis *et al* 1990) The difference in root production among root stocks of different provenances was presumably due to the amount of reserves ava lable in the roots

The highest root length recorded did not show significant d fferences among the provenances But 2nd and 3rd roots showed s gnif cant d fference among the provenances The h ghest value was shown by Nilambur provenance Th s supported an increase in average root length per growing root (Buwalda and Smith 1987) and reflected the relative rate of root efficiency The same trend is reflected in the lateral root weight also where Nilambur showed a significantly superior growth rate among the provenances A significant variation in the RGP was positively correlated with original root weight The high degree of expression in RGP might have resulted in the rapid root development as shown by Larsen (1986)

Summary

SUMMARY

A field experiment was carried out at the College of Forestry Vellanikkara to study the performance of selected provenances of *Tectona grandis* Linn F from different agroclimatic areas of Kerala The investigations were made during the period June 1995 to July 1996 Various morphological physiological anatomical characters and nutrient status dynamics were studied in teak The nursery experiment was laid out in R B D with three replications for each treatment (provenances) The salient results of the study are summarised here under

1. Seed characters of teak like mean number of seeds per kg 100 seed weight and purity percentage etc were found to vary significantly among the provenances Parambikulam was found to be superior to other provenances in this respect with better seed filling and low degree of emptiness

2. Individual seed dimensions varied considerably among the provenances Better performance in respect of seed weight seed length seed breadth and seed thickness was observed in Parambikulam indicating the superior quality of the seeds

3. Germination behaviour of seeds in the laboratory varied considerably with provenances The overall performance was better in Konni which recorded a medium performance in seed characteristics

4. Germination pattern in the field was not influenced appreciably among provenances

5 Parambıkulam N lambur and Malayattur provenances exhıbıted faster heıght growth also characterısed by quıcker radıal expansıon and superıor to the rest of provenances

6 Hıgher number of leaves and hıgher leaf area resulted ın h gh growth rate ın provenances of Parambıkulam Nılambur and Malayattur espec ally at f nal stages of the exper ment

7 Root growth pattern was ınfluenced cons derably among the provenances Root length and root dry weıght were h gher ın Paramb kulam and N lambur provenances

8 Seedl ng populat on characterıstıcs were not ınfluenced by provenance varıat on

9 Bıomass productıon wıth respect to shoot and root was affected among the provenances The hıgh shoot dry we ght of Parambıkulam Nılambur and Malayattur was the result of effect ve ut lızatıon of solar radıatıon

10 The provenances d d not show cons stent varıat on n root shoot weıght ratıo

11 The provenances dıffered sıgnıfıcantly ın spec fıc leaf area of seedl ngs Parambıkulam and N lambur was found to be the best n thıs respect espec ally at later stages

12 Parambikulam Nilambur and Malayattur recorded higher biomass accumulation as compared to the rest of the provenances This is probably because of the high RGR and NAR during the summer months

13 LDR varied nversely with water stress Generally the LDR var ed cons derably among the provenances

14 Rate of transpiration rate was found to vary among provenances The higher transpiration rate especially at the dry cycle revealed the h gher efficiency of the root system

15 Leaf temperature varied sign ficantly among the provenances During the peak period of dry cycle (180 240 DAS) a small drop of leaf temperature was observed due to the concomitant rate of transpiration in the reta ned leaves

16 Leaf water potential varied among the provenances with fluctuation of levels of water status in the so l and atmospher c temperature When the water status of the soil decreased to moderate and severe levels there was a steep decrease in leaf water potential

17 The relative water content of leaves sign ficantly var ed among provenances

18 Stomatal frequency varied n response to provenance variat on of teak A reduction in the frequency of stomates was observed in all the provenances dur ng water stressed summer months

19 Accumulation of nutrients also varied among provenances A high magn tude of Nitrogen accumulation was seen in the provenances wh ch recorded h gh rate of shoot and root growth Phosphorus concentrat on did not show any consistent pattern of accumulation among provenances Potassium concentration also followed the same trend of nitrogen concentrat on in different plant parts of seedlings

20 Uptake of nutr ents also varied in response to provenance variat on of teak Generally the uptake pattern was h gher n Paramb kulam Nilambur and Malayattur

21 The root growth potent al of teak showed signif cant var at on among provenances The number of lateral roots produced total number of tertiary roots lateral root dry weight per stump etc differed considerably among the provenances Malayattur and Nilambur had relatively h gher values in this respect

The results lead to the following conclus ons The teak seedlings showed significant variation among the provenances in most of the characters stud ed Among the seven provenances tested three provenances ie Paramb kulam Nilambur and Malayattur were found to perform better in growth attr butes physiological parameters nutrient concentration and root growth potent al Further detailed and extens ve scientific stud es have to be conducted to understand the var at ons of these provenances during various phases of growth If further experiments confirm the findings of the present nvest gat on further selection of plant stock of teak must be made from the above ment oned three provenances viz Paramb kulam N lambur and Malayattur

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Appendices

APPENDIX I

Weather parameters dur ng the study per od

Month	Weather parameters				
	Mean monthly ra nfall (mm)	Mean monthly temperature (°C)		Relat ve humid ty (%)	Number of ra ny days
		Max	M n		
Jun 95	500 4	31 6	21 1	86	19
Jul 95	884 7	29 9	23 2	89	26
Aug 95	448 7	30 6	23 7	86	22
Sep 95	282 5	30 1	23 5	82	13
Oct 95	110 4	33 2	23 2	78	8
Nov 95	88 4	31 3	22 5	80	5
Dec 95	0 0	32 5	21 3	57	0
Jan 96	0 0	33 1	22 4	53	0
Feb 96	0 0	34 7	23 4	53	0
Mar 96	0 0	36 4	24 3	60	0
Apr 96	152 0	34 6	25 0	73	7
May 96	95 4	32 8	25 2	77	4
Jun 96	400 3	30 5	23 8	85	16
Jul 96	588 7	28 8	23 1	90	25

Source Department of Agr cultural Meteorology College of Hort culture Vellanıkkara

APPENDIX XVIII

Abstract of Anova tables for Net Ass milat on Rate

Source	Degrees of freedom	Mean square	
		240 DAS	360 DAS
Provenance	6	54 723**	15 597*
Replicat on	8	47 007	10 234
Error	48	16 704	5 848
Total	62		

APPENDIX XIX

Abstract of Anova tables for leaf d ffus ve res stance

Source	Degrees of freedom	Mean square					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Provenance	6	43 695**	88 483**	115 322 *	1 737 *	8 122**	197 926*
Repl cation	8	4 244	18 569	7 539	0 779	1 156	º1 615
Error	48	2 225	4 589	6 014	2 288	4 119	80 683
Total	62						

* Sign f cant at 1% level ** Signif cant at 5% evel

APPENDIX II

Abstract of Anova table for seed characteristics

Source	Degrees of freedom	Mean square
		Weight of 10 seeds
Provenance	6	789 896**
Replication	7	7 858
Error	42	9 245
Total	55	

APPENDIX III

Abstract of Anova tables for seed characteristics

Source	Degrees of freedom	Mean square	
		Mean number of seeds per kg	Purity percentage
Provenance	6	245216 905	62 861
Replication	3	217 750	7 469
Error	18	7372 889	10 184
Total	27		

* Significant at 1% level   * Significant at 5% level

APPENDIX IV

Abstract of Anova tables for individual seed parameters

Source	Degrees of freedom	Mean square			
		Seed length	Seed width	Seed thickness	Seed weight
Provenance	6	27 500**	24 331**	14 067**	0 237**
Replication	24	2 726	2 450	1 765	0 003
Error	144	2 115	1 919	1 564	0 005
Total	174				

APPENDIX V

Abstract of Anova tables for germination behaviour of seeds in the laboratory

Source	Degrees of freedom	Mean square			
		Germi nation percentage	Germi nation value	Peak value	Mean daily germi nation
Provenance	6	331 619**	7 745*	0 585*	0 274*
Error	21	27 810	2 265	0 195	0 083
Total	27				

* Significant at 1% level ** Significant at 5% level

APPENDIX VI

Abstract of Anova tables for shoot height

Source	Degrees of freedom	Mean square			
		60 DAS	180 DAS	240 DAS	360 DAS
Provenance	6	42 924	92 645	309 800	1156 458
Replication	8	6 953	35 568	37 169	129 742
Error	48	13 158	23 604	24 296	76 446
Total	62				

APPENDIX VII

Abstract of Anova tables for collar diameter

Source	Degrees of freedom	Mean square		
		240 DAS	300 DAS	360 DAS
Provenance	6	6 988**	21 194**	127 219
Replication	8	1 397	4 865	5 536
Error	48	2 008	4 023	3 893
Total	62			

Significant at 1% level ** Significant at 5% level

APPENDIX VIII

Abstract of Anova tables for leaf production per seedling

Source	Degrees of freedom	Mean square			
		60 DAS	180 DAS	240 DAS	360 DAS
Provenance	6	6 884**	1 841 *	4 444*	7 138**
Replication	8	0 873	0 718	0 857	1 464
Error	48	2 711	0 496	0 968	0 941
Total	62				

APPENDIX IX

Abstract of Anova tables for leaf area

Source	Degrees of freedom	Mean square		
		240 DAS	300 DAS	360 DAS
Provenance	6	136615 431*	5066758 488	7205490 426
Replication	8	57414 921	1179079 988	1542902 76
Error	48	51133 667	1339855 110	1411842 430
Total	62			

* Signif cant at 1% level S gn ficant at 5% level

APPENDIX X

Abstract of Anova tables for root length

Source	Degrees of freedom	Mean square			
		60 DAS	180 DAS	240 DAS	360 DAS
Provenance	6	57 389 *	72 816**	258 350 *	734 110
Repl cation	8	9 604	49 003	45 036	158 484
Error	48	19 955	19 290	19 791	62 717
Total	62				

APPENDIX XI

Abstract of Anova tables for fresh lateral roots

Source	Degrees of freedom	Mean square			
		60 DAS	180 DAS	240 DAS	360 DAS
Provenance	6	3 138**	2 587**	1 942*	2 868 *
Replication	8	0 325	1 111	0 325	0 540
Error	48	0 524	0 611	0 626	0 808
Total	62				

* S gn ficant at 1% level   ** Sign f cant at 5% level

APPENDIX XII

Abstract of Anova tables for stem dry weight

Source	Degrees of freedom	Mean square		
		240 DAS	300 DAS	360 DAS
Provenance	6	3 731**	93 902 *	405 188 *
Repl cation	8	2 635	45 235	40 303
Error	48	2 009	23 665	23 792
Total	62			

APPENDIX XIII

Abstract of Anova tables for leaf dry we ght

Source	Degrees of freedom	Mean square
		240 DAS
Provenance	6	49 046
Replication	8	25 929
Error	48	21 756
Total	62	

* Signif cant at 1% level * S gn f cant at 5% level

APPENDIX XIV

Abstract of Anova tables for specif c leaf area

Source	Degrees of freedom	Mean square		
		240 DAS	300 DAS	360 DAS
Provenance	6	2489 758**	8409 484**	8727 042**
Repl cat on	8	42 992	1311 410	3 683
Error	48	43 226	1246 390	3 728
Total	62			

APPENDIX XV

Abstract of Anova tables for shoot dryweight

Source	Degrees of freedom	Mean square		
		240 DAS	300 DAS	360 DAS
Provenance	6	46 184**	256 400	702 427
Replication	8	2 680	99 291	96 029
Error	48	3 498	47 284	50 025
Total	62			

S gn ficant at 1% level   ** S gnificant at 5% level

APPENDIX XVI

Abstract of Anova tables for root dryweight

Source	Degrees of freedom	Mean square	
		240 DAS	360 DAS
Provenance	6	1669 294	204 016
Repl cat on	8	184 338	31 536
Error	48	216 127	25 868
Total	62		

APPENDIX XVII

Abstract of Anova tables for relat ve growth rate

Source	Degrees of freedom	Mean square
		240 DAS
Provenance	6	48 250 *
Repl cation	8	33 800
Error	48	10 595
Total	62	

* Significant at 1% level ** S gnificant at 5% level

APPENDIX XX

Abstract of Anova tables for transpiration rate

Source	Degrees of freedom	Mean square					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Provenance	6	23 317**	16 930**	11 254*	25 183**	48 741**	23 560**
Replicat on	8	2 624	2 905	2 065	5 785	8 384	2 379
Error	48	1 270	0 852	0 426	4 329	3 564	1 248
Total	62						

APPENDIX XXI

Abstract of Anova tables for leaf temperature

Source	Degrees of freedom	Mean square				
		60 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Provenance	6	20 420**	27 288**	0 539**	1 983*	20 662**
Repl cat on	8	4 947	4 448	0 011	0 186	1 844
Error	48	3 168	2 235	0 032	0 077	3 177
Total	62					

* Sign ficant at 1% level   * Signif cant at 5% level

APPENDIX XXII

Abstract of Anova tables for leaf water potent al

Source	Degrees of freedom	Mean square		
		240 DAS	300 DAS	360 DAS
Provenance	6	0 034	0 056**	0 055**
Repl cat on	8	0 080	0 088	0 002
Error	48	0 014	0 017	0 001
Total	62			

APPENDIX XXIII

Abstract of Anova tables for relative water content

Source	Degrees of freedom	Mean square					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Provenance	6	528 631**	162 397**	679 063 *	581 735 *	440 370**	531 249**
Replicat on	8	3 293	12 937	498 357	308 825	296 516	281 456
Error	48	1175 792	23 271	123 552	125 224	170 608	168 100
Total	62						

* Sign ficant at 1% level ** Significant at 5°o evel

APPENDIX XXIV

Abstract of Anova tables for stomatal frequency

Source	Degrees of freedom	Mean square					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Provenance	6	1166 75**	2610 24*	4091 29**	3010 52**	4788 36 *	1814 40*
Replication	5	179 22	1870 91	2563 43	1907 20	4551 12	1320 22
Error	30	162 60	829 63	924 37	8[illegible]6 67	581 [illegible]	778 94
Total	41						

APPENDIX XXV

Abstract of Anova tables for leaf diffusive resistance

Source	Degrees of freedom	Mean square		
		Nitrogen	Phosphorus	Potassium
Provenance	6	0 826**	0 0008*	0 086**
Replication	5	0 357	0 0002	0 004
Error	30	0 110	0 0005	0 003
Total	41			

* Significant at 1% level ** Significant at 5% level

APPENDIX XXVI

Abstract of Anova tables for nutnent concentrat on n stem

Source	Degrees of freedom	Mean square	
		Phosphorus	Potass um
Provenance	6	0 0001**	0 014**
Repl cat on	5	0 0001	0 001
Error	30	0 0001	0 003
Total	41		

APPENDIX XXVII

Abstract of Anova tables for nutr ent concentration n root

Source	Degrees of freedom	Mean square		
		Nitrogen	Phosphorus	Potassium
Provenance	6	0 249**	0 0003*	0 010**
Repl cat on	5	0 019	0 0001	0 001
Error	30	0 025	0 0003	0 001
Total	41			

* S gnificant at 1% level   ** Sign ficant at 5°o level

APPENDIX XXVIII

Abstract of Anova tables for uptake of nutrients in leaves

Source	Degrees of freedom	Mean square		
		Nitrogen	Phosphorus	Potassium
Provenance	6	83531 67*	201 96	3775 42*
Replication	2	76566 19	178 02	4992 99
Error	12	23752 53	66 04	1212 74
Total	20			

APPENDIX XXIX

Abstract of Anova tables for uptake nutrients in stem

Source	Degrees of freedom	Mean square		
		Nitrogen	Phosphorus	Potassium
Provenance	6	41992 10*	179 40	9171 29 *
Replication	2	15149 23	64 32	3519 31
Error	12	8811 54	34 22	1269 50
Total	20			

* Significant at 1% level ** Significant at 5% level

APPENDIX XXX

Abstract of Anova tables for uptake of nutr ents n root

Source	Degrees of freedom	Mean square		
		Nitrogen	Phosphorus	Potassium
Provenance	6	155771 38	127 31**	3409 54
Repl cat on	2	12201 67	28 05	637 17
Error	12	17388 54	19 31	392 46
Total	20			

APPENDIX XXXI

Abstract of Anova tables for total uptake nutrients

Source	Degrees of freedom	Mean square		
		Nitrogen	Phosphorus	Potassium
Provenance	6	702106 83**	1347 80 *	35978 8°
Repl cat on	2	194171 54	610 96	16107 38
Error	12	81349 08	221 67	5427 07
Total	20			

* S gn f cant at 1% level   ** Sign f cant at 5% evel

APPENDIX XXXII

Abstract of Anova tables for root growth potential

Source	Degrees of freedom	Mean square				
		Lateral roots per stump	Total number of tert ary roots	Dry weight of later roots	Length of lateral roots	
					2nd	3rd
Provenance	6	88 275**	22613 275*	0 005*	42 414*	45 427**
Repl cation	8	13 361	6150 004	0 002	11 575	7 890
Error	48	12 662	8841 555	0 002	18 471	0 807
Total	62					

APPENDIX XXXIII

Abstract of Anova tables for field establishment

Source	Degrees of freedom	Mean square
		Sprouts per stump
Provenance	6	17 981**
Replicat on	44	1 925
Error	264	1 000
Total	314	

* Sign f cant at 1% level ** Sign f cant at 5% level

EVALUATION OF PROVENANCES FOR SEEDLING ATTRIBUTES IN TEAK

(*Tectona grandis* Linn F)

BY

JAYASANKAR S.

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Forestry

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Department of Tree Physiology and Breeding
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Vellanikkara Thrissur

1996

ABSTRACT

A randomized block design experiment involv ng the performance of selected provenances ie Arienkavu Konni Malayattur Nilambur Parambikulam Wynad and Thrissur (Local provenance) of *Tectona grandis* Linn F nitiated during June 1995 was used for the present investigat on The object ve of the study included qualify ng the seed characteristics growth parameters physiological and anatomical characters root growth potential field establ shment and also eluc dating the extent of nutrient uptake pattern besides characterising the nutrient status dynam cs

Seed characteristics like mean number of seeds per kg 100 seed weight purity percentage and individual seed parameters were found to vary significantly among the provenances tested Paramb kulam was found to be superior to other provenances while local provenance recorded the least values for most of the parameters Germination behaviour of teak provenances n the laboratory varied cons derably among provenances The overall performance was better in Konn which recorded a h gh germ nation percentage peak value and MDG Malayattur was showed to be nfer or in these respects

Shoot root growth b omass allocation pattern RGR and NAR were followed the trend that Paramb kulam Nilambur and Malayattur cons stently reg stered better growth rates in most of the stages of exper mental period wh le local provenance recorded the least values

Physiological parameters like LDR transpiration rate leaf water potential and RWC were influenced considerably among the provenances Anatomical character like stomatal frequency was also varied among provenances throughout the period

Concentration of nutrient in the different plant parts and uptake pattern were found to be higher in Malayattur Nilambur and Parambikulam especially with a high magnitude of N use efficiency Local provenance registered a low accumulation of nutrients in different plant parts

Root growth potential studies showed significant variation among the provenances Malayattur and Nilambur provenances had relatively higher values in RGP While Thrissur recorded a poor growth performance in this respect