EVALUATION OF PROVENANCES FOR SEEDLING ATTRIBUTES IN ROSEWOOD

(Dalbergia latifolia Roxb.)

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that this thesis entitled "**Evaluation of provenances for seedling attributes in Rosewood (*Dalbergia latifolia* Roxb.)**" 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.

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CERTIFICATE

Certified that this thesis, entitled "**Evaluation of provenances for seedling attributes in Rosewood (*Dalbergia latifolia* Roxb.)**" is a record of research work done independently by **Miss.Resmi Nair, R.,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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EXTERNAL EXAMINER

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Resmi Nair.R.

Dedicated to my loving

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LIST OF ABREVIATIONS

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
RWC	-	Relative water content
PAR	-	Photosynthetically active radiation

INTRODUCTION

INTRODUCTION

Among the important species of hardwoods now widely used, rosewood plays an important role, contributing a major chunk of the hardwood needs, like ship building, construction, furniture making, panelling etc. Its natural range covers most of the sub-Himalayan tract from Oudh to Sikkim, Chota Nagpur, Central, Western and Southern India. Rosewood is a species which is widely distributed in most parts of the Indian sub-continent and it exhibits a wide range of variation (Troup, 1986).

In India the maximum number of species is found in the Western Ghats region, followed by the north-eastern region. Out of the 25 species of Dalbergia recorded from India, 22 species (one with two varieties) occur in the Western Ghats. The representation of Dalbergia species in Kerala is also very high, with 17 species and one variety, distributed almost throughout.

However, due to the slow growth rate, large-scale plantations of *Dalbergia latifolia* Roxb. are not usually established as in the case of *Tectona grandis*. But due to the important role played by rosewood, in the various needs as cited above, evolving planting materials with fast growth rate and high yield, is a major step in increasing production.

The tree is indigenous to south and South-East Asia. In India it is widely distributed from the sub-Himalayan tract to Southern India at altitudes from 0 to 900 m (1350 m in Southern India). It can be seen in various vegetation types like deciduous forests, dry forests, grasslands, moist forests, mountain forests, rain forests, and savanna woodlands. Even within a small state like Kerala, there are a lot of variation among rosewood trees. An idea of the available variation 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 (provenance) of seeds or planting materials.

Incidentally, any tree improvement programme should start with 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). So provenance tests are done to screen the naturally available genetic variability within a species and to choose the best available type for future breeding programmes. The word 'Provenance' is being used by tree breeders to mean "ultimate natural origin" (Tewari, 1994).

The present investigation is undertaken to evaluate the provenance variation for the seed and seedling characters of rosewood and to identify a few suitable seed sources for the eco-climatic conditions, prevailing in Kerala and also to help the formulation of further breeding strategy for rosewood.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The term provenance is a synonym for 'origin' or 'geographic race' (Rao, 1992) which usually denotes the original geographic area from where seeds or other propagules have been obtained. The word is being used by tree breeders to mean 'ultimate natural origin' (Tewari, 1994). However the term has been differently defined in the literature. The earliest widely accepted definitions are (i) the original geographic source of a lot of seed (or pollen) (Wright, 1962). (ii) The Society of American Foresters (1971) defined provenance as the geographic area and environment to which the parent trees are native and within which their genetic constitution has been developed through natural selection.

2.1 Genetic diversity among provenances

Success in the establishment and productivity of forest tree plantations are governed largely by the species used and the source of seed within species (Lacaze, 1978; Kumaravelu *et al.*, 1995). Most important forest tree species have one to several geographical races or provenances that possess rather large and important genetic characteristics that are unique to each. Differences among provenances are primarily caused by a few major differing gene complexes that give the source a unique advantage for growth and survival in a special environment.

Provenance trial is one of the methods used to bring improvement in tree crops and is the first step in any tree improvement programmes (Nanson, 1972). Selection of provenance is based on survey and assessment done on genetic variation (Wright, 1976). Systematic and extensive exploration and testing are required to get a sound choice of species (Burley, 1980).

Dalbergia latifolia Roxb. (family Fabaceae) belongs to the tribe Dalbergiae of subfamily Faboideae, which has been taxonomically revised by

Bentham (1860) and more recently Thottathri (1987) for the Indian subcontinent. It grows naturally in tropical and subtropical climates with a large natural distribution.

The legume genus *Dalbergia latifolia*, includes about 100 species in the world (Prani, 1904; Hutchinson, 1964; Gunn, 1983) of which more than a dozen yield the reputed rosewood of commerce. Apart from India with about 25 species (Santapau and Henry, 1973), the genus is also distributed in tropical, subtropical and warm temperate regions of the globe.

Western Ghats region in general and Kerala in particular is the largest habitat of the rosewood genus in India. This is an important factor in the conservation of the genetic diversity of the genus.In habit, Dalbergia species recorded from the Western Ghats include creepers, erect shrubs, leaves and large trees. Similarly, armed species, species with woody hooks and tendril like structures, glabrous ones, pubescent to hairy and hirsute types, etc. are also met with in this group. The habitat requirement of various species in the region are also quite varied, ranging from the wet evergreen forests in the Ghats section to the mangroove associations in the backwater areas.

2.2 Provenance testing - its importance

In order to provide a sound choice of species and provenance for planting, extensive systematic exploration and testing are required (Burley, 1980; Palmberg, 1981 and Turnbull et al., 1983).Genetic variability within a species is the basis for any tree improvement programme. The simplest method is through the exploitation of variability within a species existing between geographic sources (provenances), sites, stands, individual trees within stand and even within individual trees (Zobel and Talbert, 1984).

Forest tree improvement programme starts with the study of available variations in the entire range of species distribution of population capable of providing the best trees. This is done by provenance testing (Suri, 1984).

The opinion that the best information available in the tree improvement field relates to seed sources. The importance of seed source is emphasised by Zobel and Talbert (1984). The most successful tree improvement programmes are those in which the proper seed sources and provenances are used. In general provenance test is an experiment in which seeds are collected from a number of widely scattered stands (usually natural) and the seedlings are grown under similar climatic conditions (Wright, 1976).

Provenance testing will help to delimit the population capable of producing best trees, and also help to select the best available geographic source of seeds for afforestation or for further breeding programme. It can also be recommended for future planting programme and the provenance testing plot can be converted to seed orchards.

According to Nanson (1972), the first logical step in the breeding programme of any forest species is provenance testing. Forest tree improvement programmes start with the study of available variation in the entire range of species distribution and delimitation of population capable of providing the best tree. Generally in a provenance test, no effect is made to maintain separate identity for the offspring of individual trees within a stand.

2.2.1 Morphological and Physiological variations

Rosewood is a species which is widely distributed in most parts of the Indian subcontinent, it exhibits variations (Troup, 1986). Variations in morphological characters are shown at different sites. In drier natural habitats, *Dalbergia latifolia* sometimes sheds leaves and in moist conditions, the trees remain

evergreen throught the year. Physiological variations are not so apparent. Jones (1969) described the typical defects in the form of forking, bending etc. to be avoided during selection of plus trees. The characters like vigour, height, girth fluting, buttressing, fibril angle etc. were all reported to be heritable.

2.3 Environmental Amplitude

2.3.1 Climate

Dalbergia latifolia grows naturally in tropical and subtropical climates. In its natural habitat in India, the absolute maximum shade temperature varies from 37 to 50°C and absolute minimum from 0 to 15°C. The mean daily maximum temperature in May, which is generally the hottest month, varies from 33 to 43°C; the mean daily minimum temperature in January, which is the coldest month of the year fluctuates from 7 to 21°C. The mean annual rainfall varies from 750 to 5000 mm (Tewari, 1995), available mostly during May to September.

2.3.2 Soil and Physiography

Dalbergia latifolia grows on a variety of geological formations including gneiss, trap, laterite and alluvial formations. But it requires good drainage and reaches its best development where the soil is deep and moist, particularly in the neighbourhood of perennial storms (Troup, 1986).

According to Gupta *et al.*, 1988; Troup and Joshi, 1983, the species grows best on well drained, deep, medium textured soils, although it is also found on fine textured soils. It does not tolerate poor drainage.

Tewari (1995) explains that it occurs on deep loam and clayey soils as well as on black cotton soil, but best development is reported where the soil is deep and moist.

Dalbergia latifolia in east Jawa has been reported to improve soil physical properties such as aeration, permeability and water retention capacity (Purwanto, 1990).

Pandit *et al.*, (1988) observed higher pH in soil under *Dalbergia latifolia* when compared with *Tectona grandis* and *Terminalia elliptica*. Potassium and calcium concentrations were also higher under *Dalbergia latifolia*. Among the macronutrients, N, K and Ca were found to affect the growth of *Dalbergia latifolia* (Purwanto, 1990; Pandit *et al.*, 1988), the micronutrients Cu, Zn, Mn, Mo and B were also found to be necessary for optimum growth of the species (Kamala and Angadi, 1986; Angadi *et al.*, 1988; Kamala *et al.*, 1988).

2.4 Germination and growth characters

Dalbergia latifolia is having epigeous type of germination. It is having the capacity to reproduce itself from seed, root suckers and by coppicing. The seedlings can withstand moderate shade. All these characteristics contribute to the satisfactory regeneration of the species throughout its natural habitat (Troup and Joshi, 1983).

The natural reproduction of *Dalbergia latifolia* by seed is generally satisfactory. In natural forests, seeds germinate in the early rainy season. The main cause of mortality of seedlings is drought, especially during germination and the early development stages.

Troup and Joshi (1983), revealed that there is considerable variation in seed weight (18,500 to 40,000 seeds per kilogram). Germination takes 7 to 25 days and the germination varies from 45 to 80 per cent, and no presowing treatment was suggested.

A study done by Sharma and Potty (1999) explains the effect of plant growth regulators on rooting behaviour of cuttings of *Dalbergia latifolia* and *Dalbergia sissoo*.

In order to overcome the inherent biological problems connected with seeds, vegetative propagation could be tried as potential means of production of quality planting stock. Vegetative propagation is generally considered as important part of tree improvement programme in regeneration. The goal is to get best planting stock with the highest genetic quality materials (Hartman and Kester, 1983; Nanda, 1970; Wright, 1975).

Scientific studies and literature regarding appropriate planting technique specially for vegetative propagation of *Dalbergia latifolia* and *Dalbergia sissoo* are quite insufficient. No work has been reported on the propagation of *Dalbergia latifolia* except Negi (1982). Ansari *et al.* (1995) and Dhuria (1991) reported vegetative propagation of *Dalbergia sissoo* through cuttings.

In this study surootex-05 in powder form and IBA in 2000 ppm, 5000 ppm and 8000 ppm were taken. Cuttings of 10-15 years old plants atleast 2 nodes were secured in each cutting. Regarding rooting behaviour, *Dalbergia sissoo* performed better in comparison to *Dalbergia latifolia*. Primary roots, rooting percentage and survival of cuttings were better in *Dalbergia sissoo* than *Dalbergia latifolia*.

2.5 Variation and Breeding

Dalbergia latifolia produces valuable timber, and naturally occurring *Dalbergia latifolia* resources have become depleted in some regions.

Variations in the size and shape of leaves and fruits of *Dalbergia latifolia* have been studied by Nair (1986) based on natural populations of the species in

Kerala. Also, a germplasm bank of the species has been established at the Kerala Forest Research Institute to conserve the species and to facilitate breeding programmes. A genetic improvement programme is also being under taken in Karnataka (Prasad *et al.*, 1996).

Dalbergia latifolia is relatively slow growing, it is not much preferred as a forest plantation species at present. It is used for a range of agroforestry uses in the humid tropics. In Java it is recommended for afforestation of eroded soils (Soerianegara and Lemmens, 1993).

Compared with many tropical timber species, *Dalbergia latifolia* is slow-growing and rotations are fairly long (Troup and Joshi, 1983). The tree attains its maximum size in southern parts of India, especially in Karnataka, Kerala and parts of Tamil Nadu (Pearson and Brown, 1981).

According to Venkatesh and Kannanji (1985), provenance trials provide information on

a) Guidelines to search the naturally available variation and further selection of the best source of germplasm collection.
b) The evolutionary trends in the evolution of species, and the genetic relationship, among the species.
c) Provenance trials lead to the establishment of seed orchards.
d) Specific superior trees selected from provenances could be used for improving germplasm collection.

According to Cahalan (1989), genetic gain improvement through provenance selection is important in any tree improvement programme.

Provenance testing is an experiment in which seeds are collected from a number of widely scattered stands (usually natural) and the seedlings are grown under similar conditions (Wright, 1976). It is necessary to do provenance tests prior

to more intensive breeding work. It is also done to screen the naturally available genetic variation and to choose the best available type for reforestation or for further breeding programmes. According to Wright (1976) provenance testing is especially important when dealing with an exotic species.

2.6 General procedure for provenance testing

Generally in a provenance test no effort is made to maintain separate identity for offspring of individual trees within a stand. Burley and Wood (1976) gave a detailed description of various activities in a provenance test. In species and provenance research, site assessment is required for:

i) description of environmental conditions both at the natural range and at the prospective planning sites, and

ii) the correlation of environmental factors with attributes of tree growth (increment, form, wood quality etc.) of a given species or provenance.

Zobel and Talbert (1984) mentioned about two types of provenance tests, (i) range wide test and (ii) limited range test. In the former case, for a species with a comparatively small range, usually test trees from 20-30 localities and for species with a large range, test trees from 50-200 localities are selected. The second type which usually follows range wide tests are done to sample intensively the region(s) giving the test seeds in general.

2.6.1 General considerations

In the case of provenance selection the criteria followed are:

a) selection is confined to natural stands or from plantations raised from natural sources.

b) these should be away from other flowering plantations to avoid pollen contamination.

c) Vital data about that particular provenance also should be collected (Venkatesh and Kananji, 1985).

Site selected for trial should be a representative of the area, that is likely to be planted and should cover the extremes likely to be encounted in future. According to Harvey and Townsend (1985) in provenance testing, progenies from different parent trees are usually grown in randomised blocks with progeny from a single parent tree being grown in a randomly chosen plot within each block.

2.7 Provenance studies on various species

Provenance trial aims at getting improved knowledge about the patterns and magnitude of genetic variation in growth and other characters of a particular species. It also helps in selecting the most suitable provenance of the species for use in large scale afforestation programmes.

2.7.1 Acacias

A study done by Atipanumpai (1989) explained the variation in growth characteristics foliar nutrient concentration, phyllode anatomy and stomatal frequencies of 16 different sources in a provenance trial of *Acacia mangium* in Thailand.

Genetic variation of 16 provenances of *Acacia mangium* at nursery level in Turriabla, Costa demonstrated by Salazar (1989) revealed that seed measurement indicated considerable differences between the sources.

The performance of *Acacia mearnsii* provenance in Southern China showed that the Australian mainland provenance were superior to the Tasmanian provenances. The best provenance was 25 per cent greater than the worst (Gao and Li, 1991). Significant variations in stem height, branch, leaf and spine growth characters among the provenances of *Acacia nilotica* spp. indica were found at 6

and 23 month stage after transplantation. Provenance from North-Western and Central India were found to be superior to those from South India (Krishnan *et al.*, 1995).

Provenance evaluation and selection of *Acacia nilotica* by Pathak (1998) revealed that juvenile mature correlation identified nursery height as a potential early selection trait for increasing gain per unit time in fourth year biomass rotation trait (d.b.h., height, basal area and volume index). Volume index of superior provenance is 2-4 times significant than that of inferior ones.

2.7.2 Eucalyptus

A provenance trial involving 20 exotic provenance of *Eucalyptus microtheca* from Australia was carried out by Subramanian *et al.* (1991) to find out the best provenance for afforestation programmes. The results indicated the presence of low amount of variability among the provenance for all characters. However considering the overall growth performance of the provenance over 9 years, it appears that *Eucalyptus microtheca* is a slow growing species in comparison to the species like *Eucalyptus tereticornis* and *Eucalyptus camaldulensis*.

Performance of provenances of Eucalyptus in the dry zones of Sri Lanka was described by Vivekanandan (1981). The result showed that three provenances of *Eucalyptus tereticornis* from North Queensland grow as well in height (about 9 m) as *Eucalyptus camaldulensis* but showed better diameter at breast height (d.b.h) and stem form.

Siddique *et al.* (1979) described the results of 10 year old *Eucalyptus camaldulensis*. Dehn provenance study at Peshawar in which large and significant differences in growth characters were found between provenances consistent with

the result at six year. The lower wood density of the faster growing provenances were more than compensated by their greater volume production.

Trials of 69 provenances of Eucalyptus grandis, obtained from CSIRO, Australia and local sources established on four sites to identify provenance with good growth which are also resistant to diseases, especially pink disease have shown that after five years provenance numbers 11681 and 12081 had the best growth out of four sources all of which were free from infection in contrast to an adjacent four year old *Eucalyptus tereticornis* plantation which had a disease incidence upto 80 per cent (Deo, 1984).

2.7.3 Pines

Results on seed germination, height growth, diameter growth and survival percentage of *Pinus caribaea* was evaluated from a provenance trial at Orissa by Patnaik (1996). There was a wide variation in germination percentage among provenances but no corresponding effect on survival percentage. Another study done by Nasser *et al.* (1993) on the survival, growth, yield and wood basic density of three provenances of *Pinus patula* species and no significant differences was shown between provenances.

2.7.4 Teak

The provenance trial of teak conducted by Suri (1984) at North Raipur division of Madhya Pradesh using seeds from Maharashtra, Madhya Pradesh, Karnataka and Kerala. Among these Kerala provenances showing the best growth.

Egenti (1978), reported that provenances from India and else-where showed differences in branching habit and foliage.

Keiding (1966) suggested selection of seed production areas as an intrim source for seed collection until seed orchards are sufficiently productive.

A provenance trial for teak containing seven provenances from Kerala was done by Jayasankar *et al.* (1999). The study revealed that individual seed characteristics varied significantly among provenances and findings were consistent with the view that seed and germination characteristics were closely linked with provenance variation.

2.7.5 Dalbergia

A provenance study of *Dalbergia sissoo* was laid out at Kanpur using six provenances and all belonging to Uttar Pradesh region only (Gupta *et al.*, 1992). Data showed marked differences among the provenances.

In another study, tree height, crown spread, self pruning ability and age showed variation among provenances (Dhillon *et al.*, 1992).

Provenance trials in Dalbergia were conducted by Weil (1990) white *et al.* (1990) Singh and Danayak (1991) and Dhillon *et al.* (1995) also.

2.8 Pest and Diseases

More than 40 species of insects, including defoliators, bark feeders and sap suckers, are known to be associated with living trees of *Dalbergia latifolia*. The damage caused by them is insignificant and there is no threat from any of them in the establishment of nurseries or plantations (Mathur and Singh, 1959; Mathur and Singh, 1960; Beeson, 1941; Brown, 1968).

Intari et al. (1995) found that termites attacking *Dalbergia latifolia* were *Macrotermes gilvus* and *Odontotermes grandiceps*, while the pathogenic fungus phytophthora was found attacking the roots.

In *Dalbergia latifolia*, a total of 13 species of fungi have been reported to cause diseases of nursery seedlings, root suckers and trees in plantations and natural

stands. Among them, *Fusarium solani* (provisionally identified) which causes wilt and die back of > 15 year old trees, as reported from Indonesia, seems to be economically important (Suharti and Hadi, 1974).

Under the humid conditions of Kerala and Karnataka, the fungi *Physalospora dalbergiae, Phyllachora dalbergiae* and *Cercospora dalbergiae latifoliae* cause foliage infection in nursery seedlings, root suckers and trees in natural stands and plantations (Chiddawar, 1959; Bhat and Hegde, 1991; Sharma *et al.*, 1985).

Root rot of *Dalbergia latifolia* caused by *Phellinus gilvus* and *Coriolopsis sanguinaria* are the other minor diseases of the tree, reported from India (Bakshi, 1971, 1976).

Another study done by Naik and Lakkund (1998) explains the Tar spot of *Dalbergia latifolia* damaging the leaf area. This study explains that the species suffers from a foliage disease namely Tar spot. It is one of the main problems during nursery stage. This is caused by *Phyllochora dalbergiae* and it attacks the upper surface of the leaves and produces shining black cushion like stroma which occurs scattered or in cluster.

2.9 Experimental designs adopted

Different experimental designs are adopted which include Randomised Complete Block Design (RCBD), Incomplete Block Design, Lattice Design, Fully Randomised Design, Non-orthogonal Blocked Design, Latin squares, Family Block Design and Systematic Design.

Generally in a provenance test no effort is made to maintain separate identity for the offspring of individual trees within a stand. Wright (1978) proposed

a simplified design for combined provenance progeny testing. It is said that the combined test can be done as simply as an ordinary provenance testing.

2.9.1 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 simple analysis of data such as calculating and comparing plot or treatment and population mean values instead of complex and laborious methods like correlation and regression analysis, multivariate techniques etc.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation to evaluate the performance of five provenances of *Dalbergia latifolia* Roxb. for their seedling attributes was conducted in the farms of College of Forestry, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala. The experiments were carried out from June, 1999 to June, 2000.

3.1 Study site

Geographically, the area is located 40 m above mean sea level at 10° 32' N latitude and 76° 26' E longitude.

3.1.1 Climate

The area experiences warm and humid climate with distinct summer and rainy seasons. The weather data pertaining to the experimental period are furnished in Appendix 1.

3.1.2 Soil

The soil of the experimental site is oxisols, and was found with an average soil pH of 5.6. The soils and sub-soils were porous and extremely well drained.

3.2 Experimental materials

The experimental materials consisted of seeds collected from five provenances of *Dalbergia latifolia* Roxb. from Kerala viz. Trivandrum, Kollam, Idukki, Wyanad and Thrissur (local provenance). The details of the locality factors are given in appendix 2.

Plate 1. View of the pods of *Dalbergia latifolia* Roxb.

3.2.1 Seed sources

Seeds of *Dalbergia latifolia* Roxb. were collected from natural forest stands. 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.

3.2.2 Method of seed collection

The seeds of rosewood, start shedding during the month of May and normally continues up to July, rarely to October. 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 May, coinciding with the onset of seed fall. Seeds that are fallen at early period were discarded because of their immature nature.

The collected seeds were spread out and dried under sun, then stored in gunny bags at room temperature. About 4-6 kg of seeds could thus be obtained in a composite sample from a provenance.

3.3 Seed weight

From each of the five provenances, weight of 100 seeds was taken and repeatedly 10 times and the mean weight was recorded. Seed weight was measured by using a high precision electronic balance.

3.3.1 Individual seed characters

Length, width and thickness of 10 seeds belonging to each provenance were measured individually using high precision vernier callipers along with their individual seed weight.

3.4 Germination trial in the laboratory

Twenty plastic trays (5 provenances x 4 replications) of size 40 cm x 30 cm x 8 cm were used for conducting the germination trial. The trays were filled with finely sieved sand as germination medium, upto one centimetre below the edge of trays and well moistened. The seeds after soaking in cold water overnight for uniform germination 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 contained 25 seeds. The media was moistened uniformly on alternative days using a hand sprayer.

Observations on first seedling emergence, number of seedlings emerging on each day, number of seedling casualities, during the course of observation were recorded. From these observations, completion of germination, germination percentage, germination value, peak value and mean daily germination were computed.

The germination 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.

Plate 2. View of the seeds of *Dalbergia latifolia* Roxb.

3.5 Nursery establishment and maintenance

3.5.1 Preparation of nursery bed

Four beds of size (6 m x 1.2 m x 0.5 m), representing four replications were taken in the nursery area and each bed was split into five plots of size 1.2 m x 1 m for sowing the seeds from the five provenances. Provenances were allotted to the plots within each bed (block) randomly.

3.5.2 Pretreatment of seeds

Pretreatment is not necessary but in order to obtain good and uniform germination, seeds were subjected to soaking in cold water. Seeds were immersed in cold water during night and next day they were sown in the beds.

3.5.3 Sowing of seeds

Water soaked seeds were broadcast in respective plots of the nursery beds and covered with thin layer of soil. Each replication of every provenance had 200 seeds in it. Sowing was done on 7th June, 1999.

3.5.4 Experimental design

The experimental design adopted was Randomised Block Design (R.B.D.) with five provenances as five treatments replicated four times.

3.6 Observations recorded

3.6.1 Germination characteristics in nursery bed

After sowing the seeds on nursery beds, observations on the first seedling emergence, number of seedlings emerged on each day and number of seedling casualties during the course of observation were recorded.

From the above observations, 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 twelve plants per treatment (3 plants per replication) was done at an interval of 60 days for the experimental period of 360 days. The following biometric observations were recorded.

3.6.2.1 Shoot height

Shoot height was measured from the collar to the tip of the growing point using a meter scale and expressed in cm.

3.6.2.2 Collar diameter

The collar diameter was measured with the help of vernier callipers and expressed in mm.

3.6.2.3 Leaf production of seedlings

The number of leaves on each seedling was counted.

3.6.2.4 Leaf Area

The leaf area of individual plants were measured with Leaf 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 longest root.

3.6.2.6 Number of lateral roots

The number of lateral roots of individual seedling was counted.

3.6.2.7 Number of fresh lateral roots

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

Plate 3. View of the experimental plots of *Dalbergia latifolia* Roxb.

3.6.3 Obvservations on biomass

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

3.6.3.1 Stem weight

Average dry weight (g) of the stem excluding the leaves from the shoot for seedlings was 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 $cm^2\ g^{-1}$.

3.6.3.4 Shoot weight

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

3.6.3.5 Root weight

The average root dry weight (g) per seedlings was estimated.

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 (RGR)

Relative growth rate (RGR) was calculated from the following formula as given by Blackman (1919).

$$RGR = (\text{Log } W_2 - \text{Log } W_1) / t_2 - t_1$$

W_2 – dry weight estimate at time t_2

W_1 – dry weight estimate at time t_1

3.6.3.8 Net Assimilation Rate (NAR)

Net Assimilation Rate (NAR) is an index of the productive efficiency of plants calculated in relation to the total leaf area. NAR is calculated from the formula given below.

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

W_2 – Dry weight 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 Relative water content (RWC)

Relative water content of the leaf was determined using the following formula suggested by Barrs and Weatherly (1962). Physiologically mature leaf was selected by visual observation. Third leaf from the apex was selected and leaf punches were taken from these leaves using a steel puncher having diameter of 1.5 cm. Three samples were taken from each plot of total 12 per treatment at 1200 hrs IST and were used for estimation.

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

3.6.4.2 Chlorophyll content

Chlorophyll content of the leaf was estimated following the method suggested by Starner and Hardley (1967). From the field, twelve plants per treatment (3 plants per replication) were selected and from each plant 3 leaf samples were taken. The third leaf from the apex was taken at an interval of 120 days and the chlorophyll content was estimated. The selected samples were cut into pieces and mixed well. From this 0.1 g of the sample was weighed into a mortar and ground with a pestle to extract the chlorophyll, using 80 per cent acetone. The extract was filtered using whattman No.1 filter paper and made up to 25 ml in a volumetric flask using 80 per cent acetone. The absorbance were read in 663 nm and 645 nm, wavelengths in a spectrophotometer. The chlorophyll-A, chlorophyll-B, and total chlorophyll of each sample was calculated using the following formulae.

Chlorophyll-A (mg g^{-1} of tissue)

$$12.7\ (\text{OD at } 663 \text{ nm}) - 2.69\ (\text{OD at } 645 \text{ nm}) \times \frac{V}{1000 \times W}$$

Chlorophyll-B (mg g^{-1} of tissue)

$$22.9\ (\text{OD at } 645 \text{ nm}) - 4.68\ (\text{OD at } 663 \text{ nm}) \times \frac{V}{1000 \times W}$$

Total chlorophyll (mg g^{-1} of tissue)

$$20.2\ (\text{OD at } 645 \text{ nm}) + 8.02\ (\text{OD at } 663 \text{ nm}) \times \frac{V}{1000 \times W}$$

Where OD – optical density

V – final volume of chlorophyll extract in 80 per cent acetone

W – fresh weight of tissue extracted in grain

3.6.5 Incidence of Pest and Diseases

All the seedlings of rosewood raised from the seeds collected from five different provenances were observed throughout the experimental period from 60 to 360 days to find out the pests and diseases associated with it.

RESULTS

RESULTS

The results of the present series of investigations are presented in six main sections as, seed characters, germination characteristics, biometric observations, observations on biomass, physiological characteristics and pest and diseases.

4.1 Seed characters

Various seed characters of rosewood collected from the five different provenances are presented in table 1.

4.1.1 Hundred seed weight

Statistically significant variation in 100 seed weight, was found to be superior for the seeds from the Trivandrum provenance (Table 1). Among the five provenances, 100 seed weight was maximum for Trivandrum (4.762) and all the other provenances were on par with respect to this character.

4.1.2 Individual seed characteristics

Seed length, seed breadth and seed thickness did not show any significant variation among the provenances. But in the case of individual seed weight, the least seed weight of 0.046 g was shown by Idukki compared to others (Table 1).

4.2 Germination characteristics

The data obtained on germination of seeds from different provenances of rosewood are presented in tables 2 and 3.

4.2.1 Germination in laboratory conditions

Data furnished in table 2 show the different germination characters in laboratory conditions. There was no significant variation in the case of days taken

Table. 1. Variation in seed parameters of five rosewood provenances

Provenances	Seed length (mm)	Seed breadth (mm)	Seed thickness (mm)	Individual seed weight (g)	100 seed weight (g)
Trivandrum	7.917[a]	5.299[a]	1.596[a]	0.050[a]	4.762[a]
Kollam	7.841[a]	5.142[a]	1.573[a]	0.051[a]	4.259[b]
Thrissur	7.987[a]	4.888[a]	1.592[a]	0.049[a]	4.482[b]
Wyanad	8.134[a]	4.885[a]	1.602[a]	0.049[a]	4.293[b]
Idukki	9.973[a]	5.295[a]	1.537[a]	0.046[b]	4.323[b]
CV%	8.63	14.24	11.36	18.69	3.74
SEM±	0.218	0.23	0.057	0.003	0.074

Table 2. Germination characters in the laboratory conditions

Provenances	Days taken to complete germination	Germination percentage	Peak Value	Mean Daily Germination	Germination Value
Trivandrum	5.20[a]	75.2[a]	3.6[b]	3.6[ab]	13.2[b]
Kollam	6.00[a]	73.6[a]	4.6[ab]	3.8[ab]	17.6[ab]
Thrissur	6.40[a]	60.8[b]	3.8[ab]	3.0[b]	11.6[b]
Wyanad	6.00[a]	76.8[a]	4.8[ab]	3.4[b]	16.4[b]
Idukki	6.80[a]	69.6[ab]	5.2[a]	5.0[a]	24.6[a]
CV%	27.32	10.36	23.84	28.08	34.29
SEM±	0.743	0.825	0.469	0.472	2.558

The treatments with same alphabet do not differ significantly

to complete germination. Wyanad recorded the highest germination percentage of 76.8 which was on par with Trivandrum (75.2), Kollam (73.6) and Idukki (69.6). Mean daily germination of Idukki was superior to Thrissur and Wyanad. In the case of peak value, Idukki was superior to that of Kollam and germination value of Idukki was also superior to that of Trivandum, Thrissur and Wyanad (Fig. 1).

4.2.2 Germination characters in the field

In field conditions, significant variation was shown by the provenances (Table 3). Idukki provenance registered the highest germination percentage (69.0) which was on par with Wyanad (64.0) provenance. Thrissur provenance was having the least value of 48.5 percentage which was on par with Kollam (55.0). To complete germination, more time was taken by the seeds from Kollam (15.25) which was on par with Thrissur provenance (13.75) and the least time was taken by the seeds from Trivandrum (9.50). Mean daily germination and germination value did not show any significant variation among the provenances. Peak value of germination was superior for the Idukki provenance (6.00) than the Thrissur provenance (5.75) and was on par with the other provenances (Fig. 2).

4.3 Biometric observations

The results of the biometric observations on rosewood seedlings of different provenances at different intervals of time, are presented in tables 4 to 10.

4.3.1 Shoot height

Significant variation was observed at 60, 240 and 360 DAS among the provenances with respect to shoot height (Table 4). At 60 DAS Trivandrum and Kollam were superior than the other three provenances. Thrissur (local provenance) had low height compared to other provenances and Wyanad and Idukki were on par with respect to this character. During 240 DAS, Thrissur was inferior compared to the other provenances (Fig. 3). At 300 DAS Wyanad and

Fig. 1. Germination behaviour of rosewood provenances in the laboratary conditions

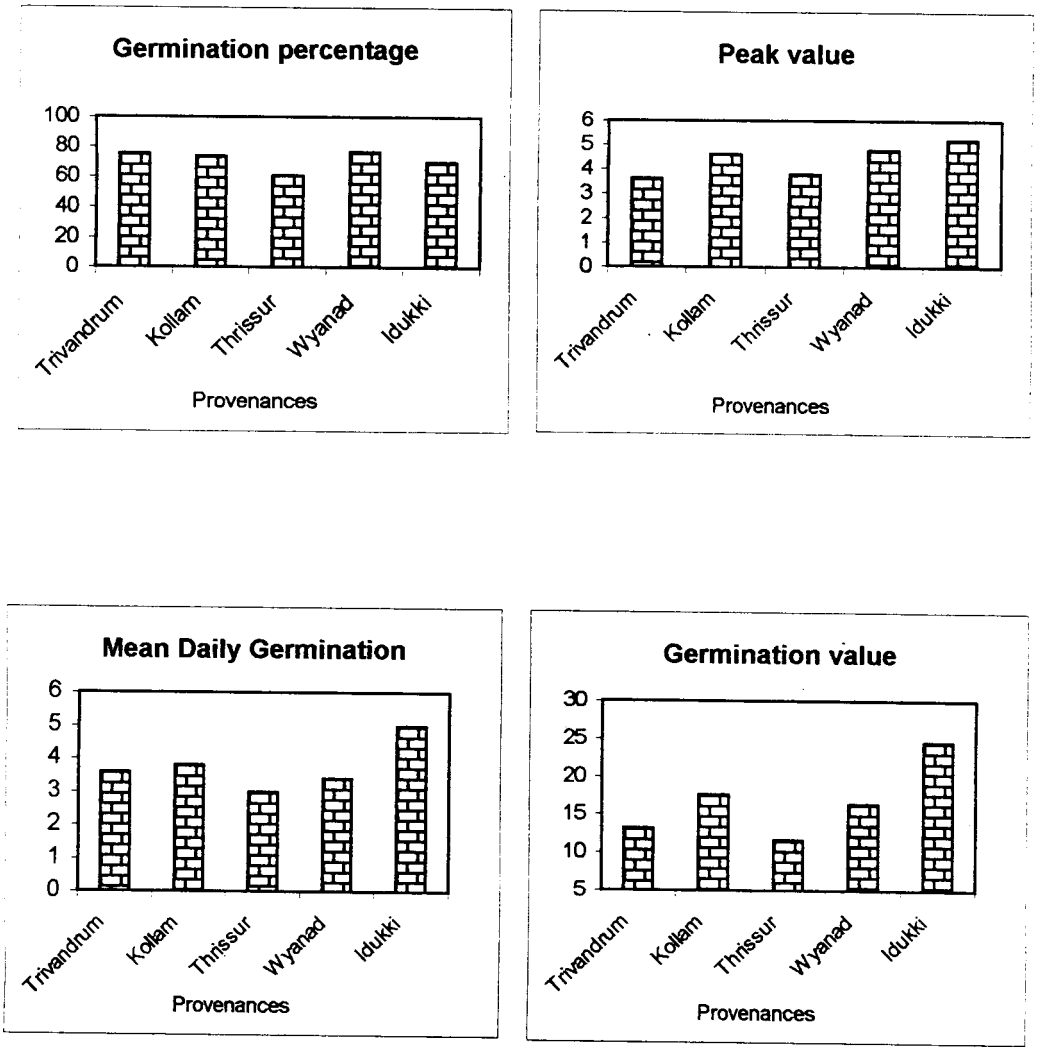


Fig. 2. Germination behaviour of rosewood provenances in the field conditions

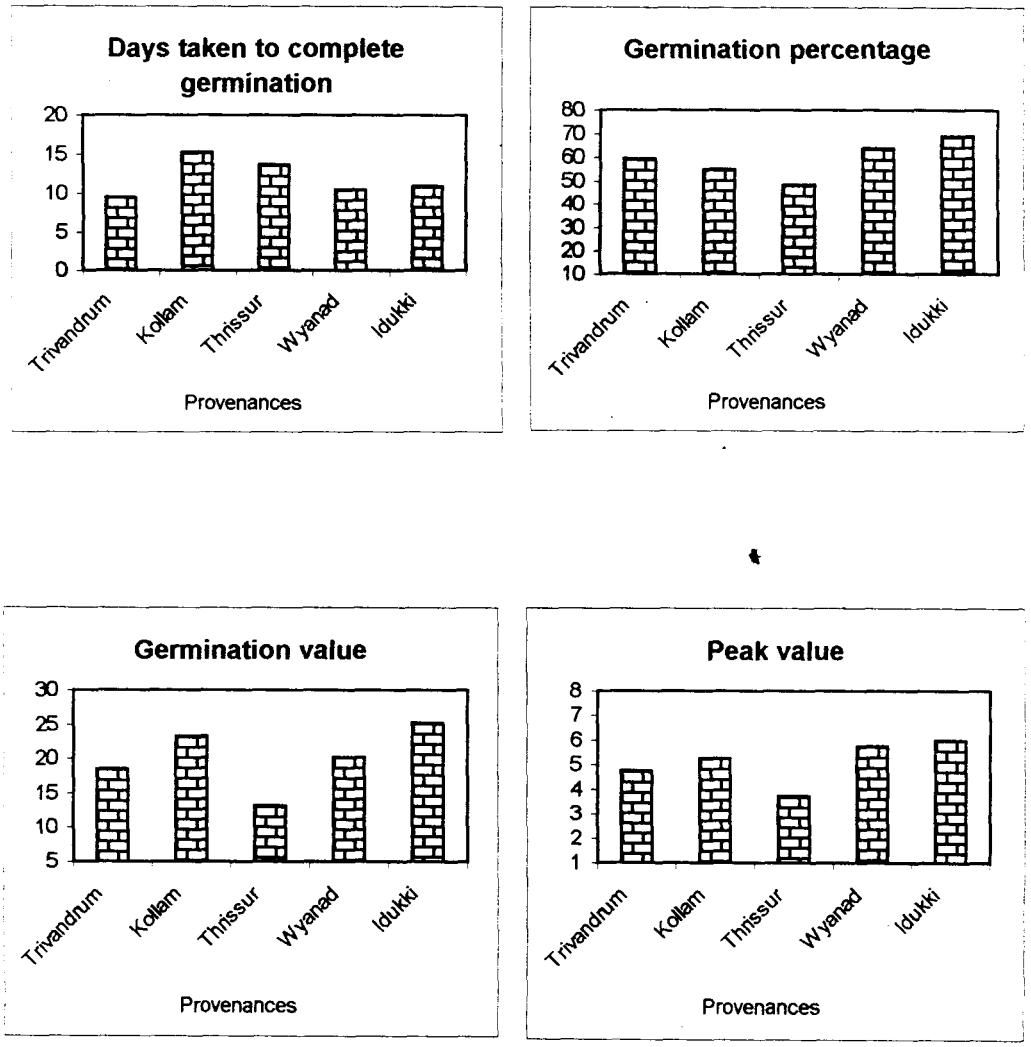


Table 3. Germination characters in the field conditions

Provenances	Days taken to complete germination	Germination percentage	Peak Value	Mean daily germination	Germination value
Trivandrum	9.50 [c]	59.38 [b]	4.75 [ab]	3.75 [a]	18.50 [a]
Kollam	15.25 [a]	55.00 [c]	5.25 [ab]	4.25 [a]	23.25 [a]
Thrissur	13.75 [ab]	48.50 [c]	3.75 [b]	3.50 [a]	13.25 [a]
Wyanad	10.50 [bc]	64.00 [ab]	5.75 [ab]	3.50 [a]	20.25 [a]
Idukki	11.00 [bc]	69.00 [a]	6.00 [a]	4.25 [a]	25.25 [a]
CV%	18.43	7.35	24.80	22.87	40.72
SEM±	1.106	3.802	0.633	0.440	4.092

Table 4. Shoot height (cm) of seedlings of five rosewood provenances

Provenances	Days after sowing					
	60	120	180	240	300	360
Trivandrum	19.42 [a]	23.88 [a]	30.77 [a]	36.10 [a]	42.92 [ab]	47.83 [bc]
Kollam	18.77 [a]	22.27 [a]	29.15 [a]	34.47 [ab]	43.83 [ab]	50.48 [abc]
Thrissur	14.33 [b]	24.90 [a]	27.95 [a]	30.52 [b]	36.47 [b]	43.25 [c]
Wyanad	15.02 [b]	23.83 [a]	26.05 [a]	38.15 [a]	49.88 [a]	57.78 [a]
Idukki	14.55 [b]	24.92 [a]	29.67 [a]	35.33 [a]	49.05 [a]	54.38 [ab]
CV%	14.05	8.83	10.59	8.26	10.33	9.44
SEM±	1.153	1.058	1.521	1.441	2.295	2.396

The treatments with same alphabet do not differ significantly

Fig. 3. Shoot height of seedlings of five rosewod provenances

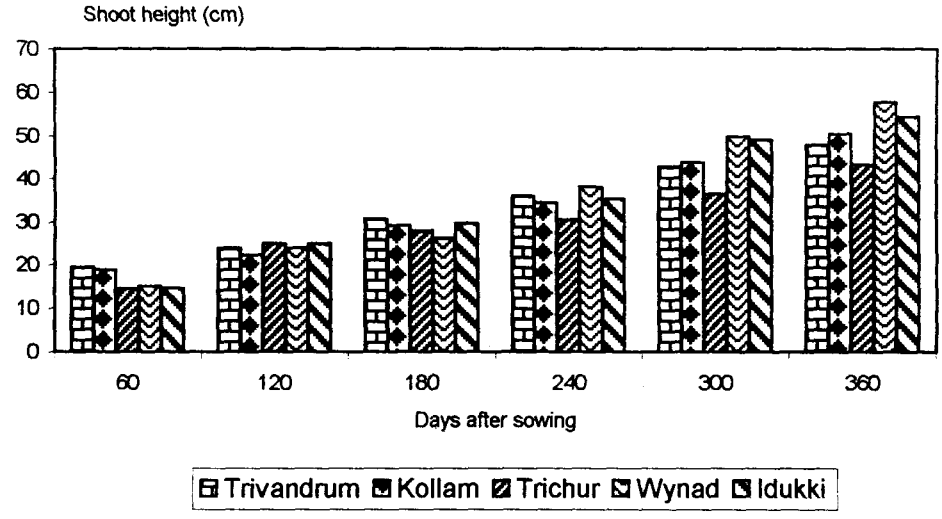
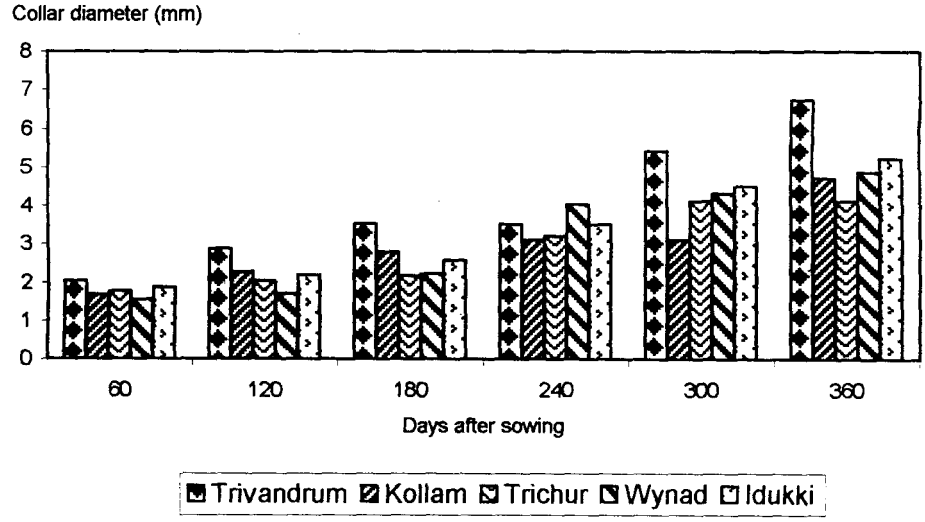


Fig. 4. Collar diameter of seedlings of five rosewod provenances



Idukki were superior than Thrissur and were on par with Trivandrum and Kollam. At 360 DAS also Thrissur registered the least value and Wyanad was superior than Trivandrum and Thrissur provenances.

4.3.2 Collar diameter

Significant difference was observed among the provenances with respect to the collar diameter except 240 DAS (Table 5). Trivandrum provenance was superior at all stages of growth. At 60 DAS, Trivandrum provenance was on par with Kollam, Thrissur and Idukki and at 300 DAS also it was on par with Thrissur and Wyanad (Fig 4).

4.3.3 No of leaves per plant

Number of leaves per plant did not show significant variation at 60, 180, 300 and 360 DAS and significant variation was shown only at 120 and 240 DAS (Table 6). There was a reduction in the number of leaves per plant during 240 DAS. Wyanad registered maximum number of leaves at 240 DAS.

4.3.4 Leaf area

Leaf area per plant did not show significant variation till 180 DAS (Table 7). From 240 to 360 DAS local provenance registered the lowest mean and at 360 it was on par with Trivandrum and Kollam.

4.3.5 Root length

A significant variation in root length was observed among provenances except at 60 and 300 DAS. Trivandrum registered the maximum root length at 120 DAS and it was on par with Kollam (Table 8). At 180 DAS Idukki become in par with Trivandrum and Kollam.Wyanad and Idukki which showed the short roots at 120 DAS, then had the longest roots at 240 DAS (Fig 5). At 300 DAS Trivandrum,

Table. 5. Collar diameter (mm) of seedlings of five rosewood provenances

Provenances	Days after sowing					
	60	120	180	240	300	360
Trivandrum	2.05[a]	2.88[a]	3.55[a]	3.53[a]	5.43[a]	6.75[a]
Kollam	1.68[ab]	2.28[b]	2.80[b]	3.13[a]	3.13[b]	4.75[b]
Thrissur	1.78[ab]	2.05[bc]	2.18[c]	3.23[a]	4.13[ab]	4.13[b]
Wyanad	1.55[b]	1.70[c]	2.23[c]	4.05[a]	4.33[ab]	4.90[b]
Idukki	1.88[ab]	2.20[bc]	2.58[bc]	3.53[a]	4.53[a]	5.25[b]
CV%	16.44	14.44	12.76	16.01	18.63	16.13
SEM±	0.147	0.160	0.170	0.279	0.401	0.416

Table. 6. Number of leaves per plant of five rosewood provenances at various stages of growth

Provenances	Days after sowing					
	60	120	180	240	300	360
Trivandrum	31.10[a]	35.83[b]	49.58[a]	57.58[b]	14.93[a]	49.40[a]
Kollam	31.10[a]	41.58[ab]	49.83[a]	53.25[b]	16.58[a]	51.85[a]
Thrissur	27.75[a]	41.65[ab]	46.83[a]	53.10[b]	12.07[a]	43.48[a]
Wyanad	29.40[a]	39.75[ab]	48.40[a]	78.50[a]	16.17[a]	60.58[a]
Idukki	28.42[a]	45.58[a]	47.22[a]	65.82[b]	16.82[a]	50.60[a]
CV%	9.36	13.97	8.71	12.67	18.85	22.32
SEM±	1.383	2.856	2.105	3.905	1.444	5.713

The treatments with same alphabet do not differ significantly

Table.7. Leaf area (cm^2) of seedlings of five rosewood provenances

Provenances	Days after sowing					
	60	120	180	240	300	360
Trivandrum	194.4[a]	277.5[a]	354.9[a]	408.8[ab]	76.25[a]	284.18[b]
Kollam	197.3[a]	283.3[a]	293.9[a]	415.8[ab]	63.19[ab]	306.45[b]
Thrissur	171.8[a]	232.8[a]	310.6[a]	397.4[b]	39.64[b]	307.23[b]
Wyanad	198.4[a]	272.3[a]	377.6[a]	499.7[ab]	84.60[a]	463.85[a]
Idukki	239.9[a]	292.2[a]	285.5[a]	536.2[a]	90.72[a]	381.93[ab]
CV%	23.01	20.63	20.45	17.89	23.83	23.20
SEM±	23.055	28.017	35.216	40.387	8.445	40.450

Table.8. Root length (cm) of seedlings of five rosewood provenances

Provenances	Days after sowing					
	60	120	180	240	300	360
Trivandrum	9.55[a]	13.52[a]	15.53[a]	16.35[b]	23.25[a]	23.73[ab]
Kollam	9.33[a]	11.40[ab]	14.52[ab]	17.17[b]	17.63[a]	21.45[bc]
Thrissur	8.15[a]	10.18[b]	10.70[b]	16.95[b]	21.90[a]	19.13[c]
Wyanad	7.63[a]	9.20[b]	11.15[b]	23.20[a]	25.00[a]	27.08[a]
Idukki	7.65[a]	9.60[b]	12.15[ab]	23.05[a]	24.58[a]	25.70[ab]
CV%	17.58	14.73	20.31	13.39	21.24	11.54
SEM±	0.744	0.794	1.301	1.296	2.386	1.351

The treatments with same alphabet do not differ significantly

Idukki and Wyanad had same root length. Performance of local provenance was inferior compared to the others at all stages of growth.

4.3.6 Number of lateral roots per plant

In the case of number of lateral roots per plant, there was no significant variation among the provenances at 180, 240 and 360 DAS. Trivandrum showed more lateral roots at 60 DAS; however Kollam, Thrissur and Wyanad provenances became on par with Trivandrum at 120 DAS (Table 9). At 180 DAS all provenances had similar number of lateral roots and they continued the status upto 240 DAS (Fig. 6). At 300 DAS Thrissur was overtaken by other provenances, though at 360 DAS all provenances were similar with respect to this character.

4.3.7 Number of fresh lateral roots per plant

The number of physiologically active lateral roots per plant (white in colour) did not show any difference except at 180 and 240 DAS (Table 10). At 180 DAS, Wyanad had higher number of fresh lateral roots compared to Thrissur. But at 240 DAS, Idukki and Trivandrum had higher number of lateral roots compared to the other three prevenances.

4.4 Biomass characteristics

The results obtained on the biomass characteristics of the rosewood seedlings of different provenances are presented in tables 11 to 18.

4.4.1 Stem dry weight

Seedlings of different provenances showed significant variation during 60, 300 and 360 DAS (Table 11). At 60 DAS Wyanad and Idukki had higher stem dry weight and was on par with Kollam. Kollam provenance was superior at 300 and 360 DAS and was on par with Idukki provenance. Local provenance showed the least values at these stages of growth.

Table 9. Number of lateral roots of seedlings of five rosewood provenances

Provenances	Days after sowing					
	60	120	180	240	300	360
Trivandrum	2.25 [a]	1.58 [a]	0.75 [a]	0.90 [a]	0.68 [ab]	0.75 [a]
Kollam	0.33 [b]	1.35 [ab]	0.98 [a]	0.75 [a]	0.75 [ab]	0.58 [a]
Thrissur	0.58 [b]	0.73 [ab]	0.50 [a]	0.43 [a]	0.48 [b]	1.10 [a]
Wyanad	0.33 [b]	0.83 [ab]	0.85 [a]	0.93 [a]	0.75 [ab]	0.75 [a]
Idukki	0.43 [b]	0.50 [b]	0.93 [a]	0.75 [a]	1.18 [a]	0.58 [a]
CV%	43.73	63.26	35.99	53.84	47.39	47.47
SEM±	0.171	0.315	0.144	0.202	0.162	0.178

Table 10. Number of fresh lateral roots of seedlings of five rosewood provenances

Provenances	Days after sowing					
	60	120	180	240	300	360
Trivandrum	4.08 [a]	4.43 [a]	6.40 [ab]	8.70 [a]	9.50 [a]	8.73 [a]
Kollam	2.93 [a]	6.10 [a]	4.50 [b]	4.68 [b]	10.85 [a]	11.60 [a]
Thrissur	3.18 [a]	6.68 [a]	7.50 [ab]	4.58 [b]	10.50 [a]	9.90 [a]
Wyanad	3.08 [a]	6.75 [a]	9.60 [a]	4.43 [b]	11.32 [a]	12.00 [a]
Idukki	3.58 [a]	6.70 [a]	7.40 [ab]	9.10 [a]	12.32 [a]	11.75 [a]
CV%	21.28	23.92	32.74	33.70	21.45	20.56
SEM±	0.358	0.733	1.159	1.061	1.169	1.109

The treatments with same alphabet do not differ significantly

Fig. 5. Root length of seedlings of five rosewod provenances

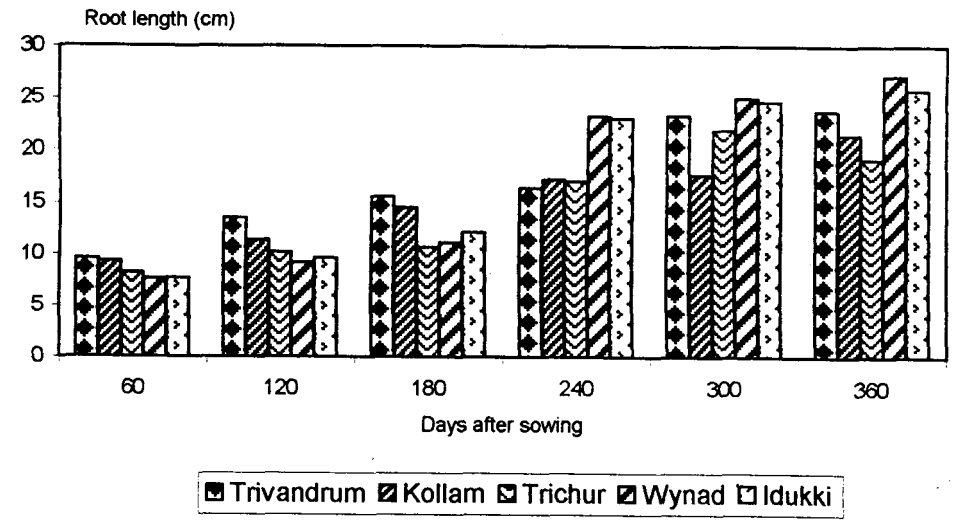
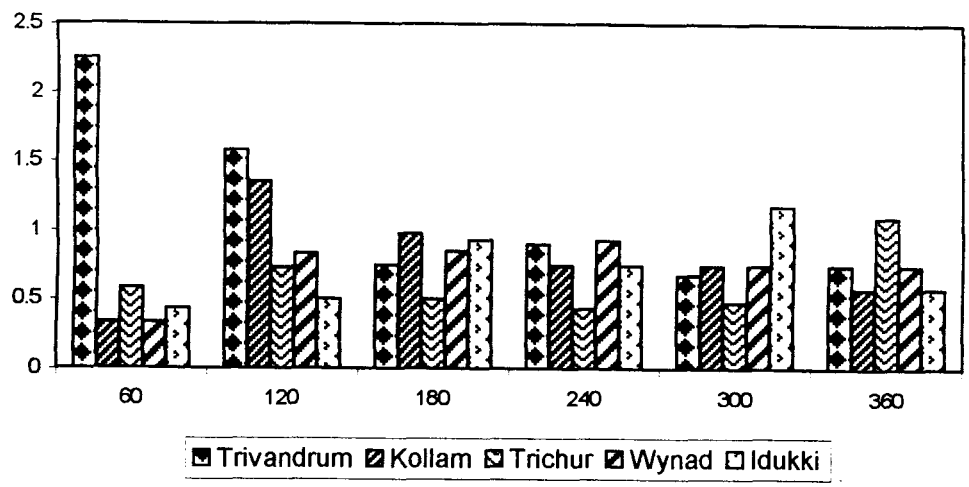


Fig. 6. Number of lateral roots of seedlings of five rosewood provenances



4.4.2 Leaf dry weight

In the case of leaf dry weight of seedlings, different provenances exhibited significant variations at 60, 120, 180 and 360 DAS (Table 12). At 60 DAS, Kollam and Wyanad was superior to Trivandrum and during 120 DAS Kollam was on par with Wyanad and superior than the others (Fig. 7). Maximum leaf dry weight was shown by Wyanad at 360 DAS and was on par with Trivandrum, Kollam and Idukki.

4.4.3 Specific leaf area

With respect to specific leaf area, except 240 and 360 DAS, there was significant difference among provenances (Table 13). At 60 DAS Trivandrum was superior than Kollam, Thrissur and Wyanad and was statistically comparable with Idukki. A similar trend was shown during 180 and 240 DAS with maximum specific leaf area for Trivandrum provenance. Thrissur and Wyanad provenances were statistically inferior than Trivandrum which were on par with Kollam and Idukki provenances.

4.4.4 Shoot dry weight

Shoot dry weight of seedlings of the provenances showed significant variation except 240 DAS. A minimum dry weight was shown by Trivandrum provenance and Wyanad was superior among the others at 60 DAS (Table 14 and Fig.8). Superior performance was exhibited by Kollam and Wyanad provenances at 120 DAS compared to the others. Higher shoot dry weight was shown by Idukki at 180 DAS and by Kollam at 300 DAS. Least significant value was recorded local provenance at 360 DAS.

4.4.5 Root dry weight

Provenances differed only at 60 and 180 DAS with respect to root dry weight of seedlings. At both these stages Idukki was superior to Thrissur. At 180 DAS, Idukki was also superior to Trivandrum (Table 15).

Table 11. Stem dry weight (g plant^{-1}) of seedlings of five rosewood provenances

Provenances	Days after sowing					
	60	120	180	240	300	360
Trivandrum	0.198 [b]	0.379 [a]	0.428 [a]	0.619 [a]	0.647 [b]	0.851 [b]
Kollam	0.317 [ab]	0.395 [a]	0.464 [a]	0.465 [a]	0.915 [a]	1.096 [a]
Thrissur	0.223 [b]	0.281 [a]	0.354 [a]	0.480 [a]	0.475 [b]	0.800 [b]
Wyanad	0.378 [a]	0.464 [a]	0.478 [a]	0.383 [a]	0.550 [b]	0.680 [b]
Idukki	0.351 [a]	0.470 [a]	0.536 [a]	0.488 [a]	0.690 [ab]	0.847 [ab]
CV%	26.92	34.89	23.74	42.57	23.26	18.31
SEM±	0.039	0.069	0.054	0.104	0.076	0.078

Table 12. Leaf dry weight (g plant^{-1}) of seedlings of five rosewood provenances

Provenances	Days after sowing					
	60	120	180	240	300	360
Trivandrum	0.323 [b]	0.369 [c]	0.379 [c]	1.170 [a]	0.029 [a]	1.004 [ab]
Kollam	0.562 [a]	0.741 [a]	0.717 [ab]	0.842 [a]	0.035 [a]	0.858 [ab]
Thrissur	0.487 [ab]	0.543 [bc]	0.563 [bc]	1.063 [a]	0.039 [a]	0.710 [b]
Wyanad	0.661 [a]	0.694 [ab]	0.686 [ab]	0.832 [a]	0.073 [a]	1.188 [a]
Idukki	0.517 [ab]	0.550 [bc]	0.885 [a]	1.100 [a]	0.068 [a]	0.965 [ab]
CV%	25.48	19.30	20.46	32.17	54.56	28.31
SEM±	0.065	0.056	0.066	0.161	0.013	0.134

The treatments with same alphabet do not differ significantly

Table 13. Specific leaf area ($cm^2\ g^{-1}$) of seedlings of five rosewood provenances

Provenances	Days after sowing					
	60	120	180	240	300	360
Trivandrum	636.4 [a]	758.9 [a]	975.8 [a]	366.4 [a]	3903.0 [a]	292.8 [a]
Kollam	376.6 [b]	404.4 [b]	457.9 [b]	597.1 [a]	2427.0 [ab]	370.4 [a]
Thrissur	367.1 [b]	432.1 [b]	570.5 [b]	439.4 [a]	1448.0 [b]	473.5 [a]
Wyanad	312.7 [b]	409.0 [b]	576.6 [b]	696.4 [a]	1307.0 [b]	454.1 [a]
Idukki	490.7 [ab]	541.0 [b]	438.9 [b]	555.0 [a]	1696.0 [ab]	396.8 [a]
CV%	30.90	20.85	37.88	51.50	68.31	42.74
SEM±	67.474	53.075	114.375	136.697	736.527	84.959

Table 14. Shoot dry weight (g $plant^{-1}$) of seedlings of five rosewood provenances

Provenances	Days after sowing					
	60	120	180	240	300	360
Trivandrum	0.521 [c]	0.749 [b]	0.807 [c]	1.789 [a]	0.677 [b]	1.323 [ab]
Kollam	0.879 [ab]	1.136 [a]	1.181 [ab]	1.306 [a]	0.949 [a]	1.198 [ab]
Thrissur	0.710 [bc]	0.825 [b]	0.917 [bc]	1.543 [a]	0.513 [b]	1.013 [b]
Wyanad	1.039 [a]	1.158 [a]	1.164 [ab]	1.215 [a]	0.622 [b]	1.543 [a]
Idukki	0.869 [ab]	1.020 [b]	1.421 [a]	1.588 [a]	0.757 [ab]	1.368 [ab]
CV%	23.61	11.81	15.61	33.80	21.74	23.92
SEM±	0.095	0.058	0.086	0.252	0.077	0.154

The treatments with same alphabet do not differ significantly

Fig. 7. Leaf dry weight of seedlings of five rosewod provenances

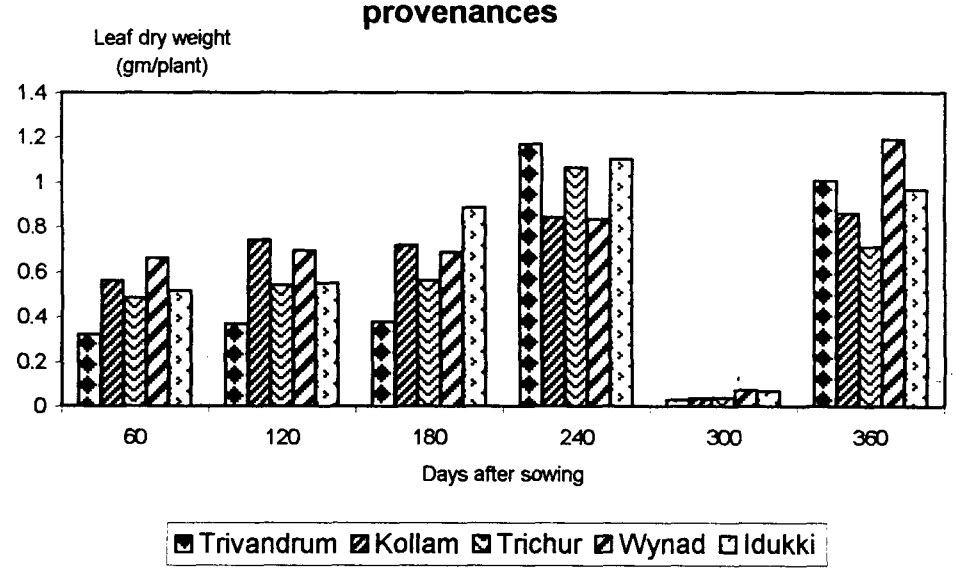
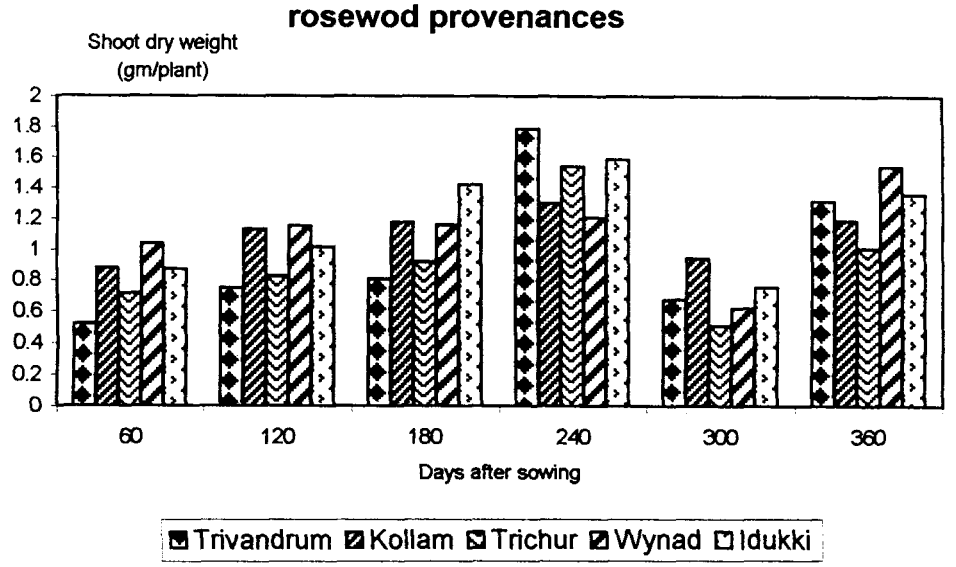


Fig. 8. Shoot dry weight of seedlings of five rosewod provenances



4.4.6 Root-shoot ratio

With respect to root-shoot ratio, seedlings of different provenances did not show any significant difference at any stage of the experimental period (Table 16).

4.4.7 Relative growth rate (RGR)

The mean values of the relative growth rate of seedlings of different provenances showed highly significant variation (Table 17). At 120 and 240 DAS Trivandrum was superior compared to others, but was on par with Kollam and Thrissur at 120 DAS. Idukki and Kollam provenances were statistically superior than the other provenances at 180 and 300 DAS (Fig. 9) suspectively. At 360 DAS Kollam was superior than the Thrissur provenance which was on par with the others.

4.4.8 Net assimilation rate (NAR)

Different provenances exhibited significant difference with respect to NAR only at 300 DAS (Table 18). At 300 DAS Kollam registered the highest mean of 0.099 which was on par with Wyanad and Idukki.

4.5 Physiological characters

Results of the physiological characters are given in tables 19 to 22.

4.5.1 Relative water content (RWC)

Relative water content of the leaves of seedlings of different provenances showed statistically significant variation during 60, 300 and 360 DAS. Idukki provenance recorded the highest RWC of 15.68 at 60 DAS and at 300 DAS Kollam provenance was superior to the others. Local provenance registered the least value at all these stages and at 360 DAS Kollam registered the highest value (Table 19 and Fig.10) which was on par with Trivandrum, Wyanad and Idukki provenance.

Table 15 Root dry weight (g plant^{-1}) of seedlings of five rosewood provenances

Provenances	Days after sowing					
	60	120	180	240	300	360
Trivandrum	0.254 ^{ab}	0.319 ^{a}	0.354 ^{b}	0.524 ^{a}	0.530 ^{a}	0.681 ^{a}
Kollam	0.275 ^{ab}	0.341 ^{a}	0.393 ^{ab}	0.428 ^{a}	0.731 ^{a}	0.800 ^{a}
Thrissur	0.185 ^{b}	0.304 ^{a}	0.350 ^{b}	0.343 ^{a}	0.496 ^{a}	0.698 ^{a}
Wyanad	0.279 ^{ab}	0.355 ^{a}	0.496 ^{ab}	0.378 ^{a}	0.516 ^{a}	0.585 ^{a}
Idukki	0.356 ^{a}	0.404 ^{a}	0.538 ^{a}	0.445 ^{a}	0.581 ^{a}	0.764 ^{a}
CV%	37.31	38.02	23.20	52.17	32.19	24.94
SEM±	0.050	0.066	0.049	0.111	0.092	0.088

Table 16 Root shoot ratio of seedlings of five rosewood provenances

Provenances	Days after sowing					
	60	120	180	240	300	360
Trivandrum	0.485 ^{a}	0.448 ^{a}	0.475 ^{a}	0.297 ^{a}	1.038 ^{a}	0.525 ^{a}
Kollam	0.308 ^{a}	0.297 ^{a}	0.333 ^{a}	0.300 ^{a}	0.777 ^{a}	0.685 ^{a}
Thrissur	0.286 ^{a}	0.365 ^{a}	0.354 ^{a}	0.231 ^{a}	1.011 ^{a}	0.721 ^{a}
Wyanad	0.336 ^{a}	0.310 ^{a}	0.427 ^{a}	0.349 ^{a}	0.873 ^{a}	0.424 ^{a}
Idukki	0.417 ^{a}	0.390 ^{a}	0.380 ^{a}	0.302 ^{a}	0.758 ^{a}	0.553 ^{a}
CV%	32.51	39.41	29.53	37.31	38.98	31.61
SEM±	0.060	0.071	0.059	0.055	0.174	0.092

The treatments with same alphabet do not differ significantly

Table 17. Relative growth rate (g g^{-1} $week^{-1}$ x 10^{-2}) of seedlings of five rosewood provenances

Provenances	Days after sowing					
	60	120	180	240	300	360
Trivandrum	-	0.111 [a]	0.103 [b]	0.122 [a]	0.073 [c]	0.577 [ab]
Kollam	-	0.109 [ab]	0.102 [b]	0.096 [c]	0.100 [a]	0.478 [b]
Thrissur	-	0.108 [ab]	0.104 [b]	0.111 [b]	0.075 [c]	0.588 [a]
Wyanad	-	0.105 [b]	0.103 [b]	0.098 [c]	0.087 [b]	0.577 [ab]
Idukki	-	0.105 [b]	0.111 [a]	0.099 [c]	0.085 [b]	0.545 [ab]
CV%		7.05	11.57	3.95	16.20	15.97
SEM±		0.0038	0.0320	0.0021	0.0085	0.0067

Table 18. Net assimilation rate (g g^{-1} $week^{-1}$ x 10^{-2}) of seedlings of five rosewood provenances

Provenances	Days after sowing					
	60	120	180	240	300	360
Trivandrum	-	0.008 [a]	0.007 [a]	0.008 [a]	0.088 [b]	0.113 [a]
Kollam	-	0.008 [a]	0.007 [a]	0.007 [a]	0.099 [a]	0.112 [a]
Thrissur	-	0.008 [a]	0.007 [a]	0.008 [a]	0.086 [b]	0.114 [a]
Wynad	-	0.008 [a]	0.007 [a]	0.007 [a]	0.096 [a]	0.110 [a]
Idukki	-	0.007 [a]	0.008 [a]	0.007 [a]	0.095 [a]	0.110 [a]
CV%		6.98	3.69	12.94	6.85	2.93
SEM±		0.0003	0.0001	0.0005	0.0032	0.0016

The treatments with same alphabet do not differ significantly

Fig. 9. Relative growth rate of seedlings of five rosewod provenances

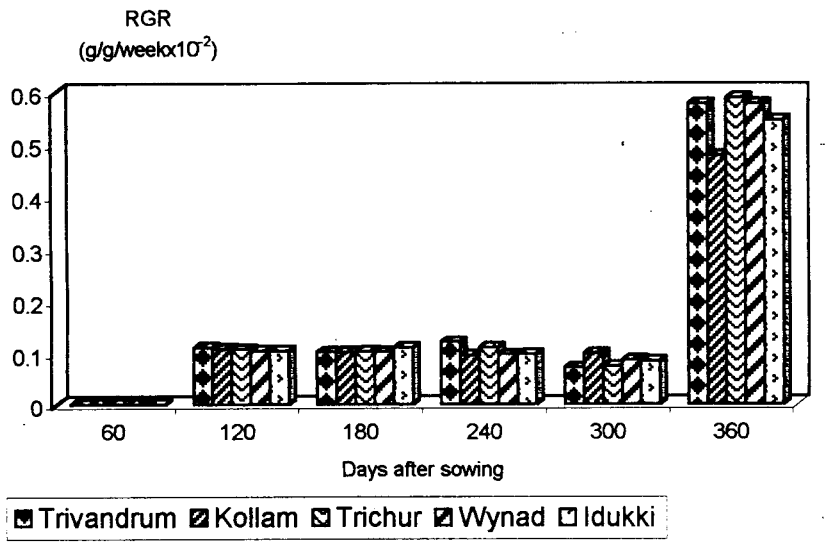
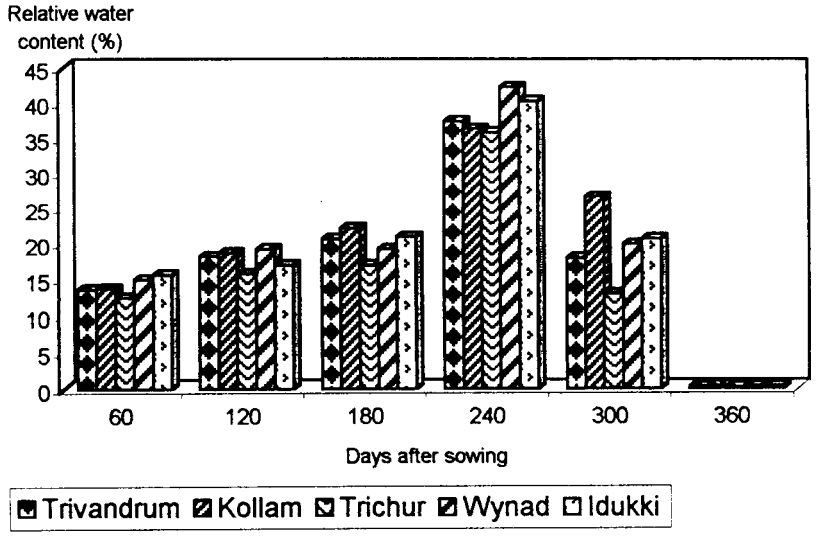


Fig. 10. Relative water content of seedlings of five rosewod provenances



4.5.2 Chlorophyll content

4.5.2.1 Chlorophyll-A

In the case of chlorophyll-A content, there was no statistical difference among the provenances (Table 20). In all the cases Idukki showed higher mean values followed by Kollam.

4.5.2.2 Chlorophyll-B

In this case also there was no statistical difference between the provenances (Table 21). At 240 and 360 DAS Trivandrum showed higher mean values which was having the lowest mean at 120 DAS.

4.5.2.3 Total chlorophyll

With respect to total chlorophyll content also provenances did not show any significant difference (Table 22). Higher mean values were registered by Trivandrum at 240 and 360 DAS as in the case of chlorophyll-B content.

4.5.3 Incidence of Pests and Diseases

None of the provenances used for the experiment was susceptible to any major diseases, nor there was any serious pest attack. However during the initial stage, there was minor occurrence of termites, which was controlled by drenching the nursery beds with chlorpyriphos at the rate of 3 ml per litre.

Table 19. Relative water content (%) of seedlings of five rosewood provenances

Provenances	Days after sowing					
	60	120	180	240	300	360
Trivandrum	13.59 [c]	18.25 [a]	20.78 [a]	37.54 [a]	18.10 [b]	0.23 [bc]
Kollam	13.72 [c]	18.78 [a]	22.34 [a]	36.49 [a]	26.84 [a]	0.38 [a]
Thrissur	12.42 [d]	15.82 [a]	17.03 [a]	35.99 [a]	13.06 [c]	0.19 [c]
Wyanad	14.97 [b]	19.31 [a]	19.35 [a]	42.32 [a]	20.08 [b]	0.31 [ab]
Idukki	15.68 [a]	17.04 [a]	21.08 [a]	40.35 [a]	20.88 [b]	0.33 [ab]
CV%	11.79	21.53	24.36	10.20	14.92	26.71
SEM±	0.008	0.019	0.025	0.020	0.015	0.039

Table 20. Chlorophyll- A mg g^{-1} of seedlings of five rosewood provenances

Provenance	Days after sowing		
	120	240	360
Trivandrum	1.214 [a]	0.946 [a]	0.972 [a]
Kollam	0.836 [a]	0.773 [a]	0.902 [a]
Thrissur	1.107 [a]	0.654 [a]	0.694 [a]
Wyanad	1.336 [a]	0.764 [a]	0.897 [a]
Idukki	1.233 [a]	1.040 [a]	0.945 [a]
CV%	26.05	27.47	22.49
SEM±	0.1492	0.1147	0.0992

The treatments with same alphabet do not differ significantly

Table 21. Chlorophyll- B mg g^{-1} of seedlings of five rosewood provenances

Provenance	Days after sowing		
	120	240	360
Trivandrum	0.477 [a]	0.967 [a]	0.997 [a]
Kollam	0.614 [a]	0.738 [a]	0.823 [a]
Thrissur	0.541 [a]	0.792 [a]	0.616 [a]
Wyanad	0.580 [a]	0.752 [a]	0.801 [a]
Idukki	0.501 [a]	0.867 [a]	0.971 [a]
CV%	31.27	19.69	33.76
SEM±	0.0848	0.0810	0.1421

Table 22. Total Chlorophyll mg g^{-1} of seedlings of five rosewood provenances

Provenance	Days after sowing		
	120	240	360
Trivandrum	1.687 [a]	1.869 [a]	1.968 [a]
Kollam	1.447 [a]	1.329 [a]	1.725 [a]
Thrissur	1.645 [a]	1.318 [a]	1.310 [a]
Wyanad	1.912 [a]	1.360 [a]	1.697 [a]
Idukki	1.730 [a]	1.771 [a]	1.915 [a]
CV%	26.34	29.22	27.59
SEM±	0.2218	0.2235	0.2377

The treatments with same alphabet do not differ significantly

DISCUSSION

DISCUSSION

Evaluation on rosewood (*Dalbergia latifolia* Roxb.) collected from five provenances was carried out at Vellanikkara, Thrissur during 1999-2000 to compare variations, if any, in their seed characters, germination characters, biometrical and physiological characters. Most of the characters showed significant variation among the provenances. The important findings obtained in this study are discussed here under.

5.1 Seed characters

Statistically significant variation were observed among the five provenances with respect to 100 seed weight. The seeds from Trivandrum provenance was found to be superior in this respect compared to the others. In the case of individual seed weight also significant variation was there and the minimum seed weight was for the seeds from Idukki provenance and all the others were on par. Significant variation in seed weight can be genetic variation among provenances and this variation can be among families within provenance as reported by Smizko and Stewart (1989) in *Acacia albida.*

Environmental influence during the development of seeds with genetic variability can result in variations in seed dimensions according to Willan (1985). The higher seed weight could be attributed to better growth characters. Similar results have been observed in teak by Jayasankar *et al.* (1999).

Individual seed characteristics, like seed length, breadth and thickness did not show any significant differences among provenances. The characters with no difference, genetics may be playing more role and not the physiological aspects. According to Negi and Jodaria (1997), there is a close relationship between seed size and seed quality. The bigger seed size reflected in better and uniform variability and germination in *Grewia optiva* Dummond. (Jaswal, 1992).

Assessment for bigger seed size may be useful in having a uniform and better plantable stock.

Roychoudhary (1961) in paddy and Bagchi and Sharma (1989) in *Santalum album* observed that individual seed parameters were independently controlled and sufficient variability existed for selection. In a broader perspective, it is said that the larger sized seeds have greater advantages over the smaller sized seeds with reference to germination and further performance of the seedlings.

5.2 Germination characters

Significant variation was observed in germination characters except in the case of days taken to complete germination. In this study it was observed that Wyanad provenance recorded the highest germination percentage (76.8) and was immediately followed by Trivandrum provenance (75.2). Bahuguna *et al.* (1988) reported that the sowing media significantly affected the seed germination.

A study by Troup and Joshi (1983) in *Dalbergia latifolia* Roxb. reported that germination takes seven to twenty five days and the germination varies from 45 to 80 per cent. Germination has been reported very good in the case of *Populus gamblei* Dode., when the seeds were sown in trays than in nursery beds (Palet, 1980). Similar result was obtained in the present study also. Peak value, mean daily germination and germination value were the highest for the Idukki provenance. Along with the local provenance, Wyanad recorded the least values for mean daily germination and germination value which was having the highest germination percentage.

Under field conditions significant variation was shown by the provenances. Idukki registered the highest germination percentage (69.0) which was on par with Wyanad provenance (64.0). Peak value was also superior for Idukki provenance and was comparable with the others except local provenance with least value (3.75). To complete germination more time was taken by the seeds

from Kollam (15.25) which was on par with Thrissur and Trivandrum provenances. Mean daily germination and germination value did not show any significant variation among the provenances. According to Sremathi *et al.* (1991) heavy and large seeds performed better in terms of germination pattern. Significant variation in seed germination among provenances was also reported in *Acacia mangium* (Salazar, 1989), *Dalbergia sissoo* (Dhillon *et al.*, 1995) and *Gliricidia sepium* (Nugulube, 1989).

Veerendra *et al.* (1996) reported that provenance variation in the case of seed characters like length, width and 100 seed weight of neem seeds reveals the genetic variability among the provenances.

Farmer (1980) rerported that more quantity of stored food materials in the heavy seeds might have contributed for early and better germination of heavy seeds. But the present study contradicts the above findings, because the individual seed weight was least for the Idukki provenence. From the above observations, it is seen that there is significant variation among provenances for most of the characters studied and none of the provenances showed highest value for all the characters, suggesting wide genotypic variations among populations in each povenances. Thrissur (local provenance) was having the least values for all the characters with statistically significant variation. So it can be presumed that, Thrissur is a genotypically poor performer and the Idukki provenance which registered higher mean values for most of the significant characters as a statistically superior performer.

5.3 Biometric observations

Except leaf area all the biometric characters showed significant variation among the provenances.With respect to shoot height, except 120 and 180 DAS significant variation was there. At 60 DAS Trivandrum and Kollam were superior over the others. Wyanad and Idukki which registered the least values at 60

DAS were superior towards the later stages of growth. Sobor (1979) in *Gliricidia sepium* found that there is a positive correlation between seed weight and seedling height. Nugulube (1989) also stated that provenance with higher germination percentage also have greater potential for height growth. At all stages of growth local provenance registered the least value.

In the case of root length and collar diameter also Trivandrum and Kollam provenances were superior at early stages of growth. Glover (1987) reported that a favourable interaction between provenance and the environment, resulted in superior seedlings.

Nanda *et al.* (1970) demonstrated that seasonal changes in auxins can effect the rooting pattern. This in turn are caused by temperature and day light changes experienced during annual cycle of plant growth. The similar result was also obtained by Bhatt (1990) for forage stage.

But in the case of root length during dry spell, the extent of growth was more compared to rainy season. This can be due to the dry spell that was prevailing during that period, the root systems are getting adjusted for more absorption of water which is a physiological adjustment. This can be supported by the fact that moisture may be a limiting factor during the dry months (Hazlet, 1989). Observations of the present study also indicated that the provenances, which were better in terms of height growth had a positive relationship with height and girth increments.

Statistically significant variation was observed for number of leaves per plant and leaf area among the different provenances. Only at 120 and 240 DAS significant variation was there for number of leaves per plant and at 240, 300 and 360 DAS showed significant difference for leaf area.

More number of leaves and higher leaf area presumably indicate that more biomass is allocated to the leaves, compared to shoot and roots in order to

increase the photosynthetic efficiency of the plants. Wierland (1985) noted that plants with higher rate of leaf growth probably had a higher photosynthetic efficiency and growth potential. The Wyanad provenance was superior with respect to the number of leaves per plant at both stages (120 and 240 DAS) of growth. But for leaf area both Wyanad and Idukki provenances performed better. The leaf shedding time during (February-March) can be a physiological adjustment during the dry spell to reduce the rate of transpiration.

Kadambi (1949) had observed that Dalbergia latifolia sheds leaves in drier habitats (either partially or sometimes fully) and in moist conditions, the trees remain evergreen throughout the year.

Presence of lateral roots and fresh lateral roots per plant show significant variation among the provenances at 60, 120 and 300 DAS and at 180 and 240 DAS. At 60 DAS, Trivandrum was superior over the others for number of lateral roots and at 120 and 300 DAS Trivandrum, Kollam and Wyanad were on par. Idukki provenance which was having an inferior performance at 60 and 120 DAS was superior at 300 DAS. In the case of physiologically active roots at 180 and 240 DAS both Trivandrum and Idukki were superior.

As a general trend, plants with more height growth allocated almost equal biomass into its underground parts. It appears that the development of roots is governed by genetic factors (Glover, 1987).

A study by Goldbold *et al.* (1988) in *Picea abies* reveals that fresh roots are responsible for the absorption of water and nutrients in large amounts. In this respect, it may be remembered that Trivandrum and Idukki provenances which showed higher number of lateral roots and physiological active roots also showed a relatively higher shoot height. The performance of local provenance was inferior compared to the others with least mean values.

5.4 Biomass characteristics

Biomass production plays an important role in the ultimate biological yield. Total biomass production is known to be strongly genetically controlled and can be considered as a parameter for selection of superior genotypes.

In the present study, variation between provenances existed for the various biomass characters such as stem, leaf, root and shoot dry weight. At 60, 300 and 360 DAS, Kollam and Idukki were superior for stem dry weight and Wyanad was on par with them only at 60 DAS. Kollam, Wyanad and Idukki were statistically comparable at 60, 180 and 360 DAS with respect to leaf dry weight. Similar result was observed for shoot dry weight also. In the case of root dry weight, at 60 and 180 DAS Kollam, Wyanad and Idukki were superior among the provenances.

Hazara and Tripathi (1986) reported that biomass production is a function of the photosynthetically active radiation (PAR) falling on the leaves. The present study also highlights the fact that optimal leaf mass levels would substantially increase the biomass production. It is presumed that the available solar energy was more effectively used by Wyanad and Idukki provenances by their highest leaf number and leaf area. In this perspective Idukki and Wyanad provenances with its superior height growth coupled with superior shoot, leaf and root dry weight holds more promise.

In the case of specific leaf area the results were inferior for Wyanad and Idukki provenances. Both of them registered the least values at different stages of growth. Response of the plants in specific leaf area, is positively related to water absorption (Grier and Running, 1977).

The total dry matter production 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 reduction in dry matter production is directly related to the decrease in the number of leaves, which are positively correlated with the total biomass production. Busgen and Munch (1937) reported that external environmental factors influence growth rate and dry matter accumulation in plant parts to a great extent.

The root-shoot ratio of seedlings of different provenances did not show any significant difference at any of the growth period.

Significant variation was observed among the provenances with respect to relative growth rate. But in the case of net assimilation rate significant difference was observed only at 300 DAS. At 120 and 240 DAS, Trivandrum was superior compared to the others with respect to relative growth rate but was on par with Kollam and Thrissur at 120 DAS. Idukki and Kollam were superior at 180 and 300 DAS. Kollam registered the highest mean for net assimilation rate at 300 DAS which was on par with Wyanad and Idukki provenances.

The leaves maintained high efficiency with respect to dry matter production as indicated by the data on RGR which were relatively stable as compared to other provenances. Maguire *et al.* (1990) stated that relative growth rate is a function of the dry matter accumulation.

Net assimilation rate generally points to an increase in efficiency of the available leaf area. But the present study does not support the above mentioned theory, as significant difference was observed only at 300 DAS.

5.5 Physiological parameters

Relative Water Content (RWC) of the seedlings of different provenances showed significant variation at the initial stage (60 DAS) and to the later stages (300 and 360 DAS). After the dry spell also the RWC showed a decline, which indicates that the RWC is considered as a character of stress

intolerant species (Cowan, 1981). Idukki recorded the highest value at 60 DAS and Kollam was superior at 300 and 360 DAS.

Regarding chlorophyll content there was no statistical difference among the provenances at any of the experinmental period. Bray (1960) has reported that chlorophyll content greatly influences the growth of the individual. Chlorophyll content in plants decides their photosynthetic potential. Therefore an estimate of chlorophyll A, B and total chlorophyll of the different provenances will provide information regarding this varying biochemical parameter which ultimately will be contributing to the total biomass. But in the present study significant variation was not observed among the provenances.

SUMMARY

SUMMARY

A field experiment was carried out at the Forestry College, Vellanikkara to study the performance of selected provenances of *Dalbergia latifolia* Roxb. from different agroclimatic regions of Kerala. The investigations were made during the period of June 1999 to June 2000. Various morphological and physiological characters were studied in rosewood. The nursery experiment was laid out in R.B.D. with four replications for each treatment (provenance). The salient observations are as follows:

1. Statistically significant vatiation in 100 seed weight was found to be superior for the seeds from Trivandrum provenance. Trivandrum was found to be superior than the others with better seed filling and low degree of emptiness.
2. Individual seed characteristics like seed breadth, length and thickness did not show any significant variation among the provenances. But in the case of individual seed weight significant variation was shown and the least seed weight was shown by the Idukki provenance and the others were on par.
3. Significant variation in germination characters under field conditions were shown by the provenances except in the case of time taken to complete germination. Highest germination per centage was superior for wyanad provenance and with respect to peak value,mean daily germination and germination value Idukki was superior over the others.
4. Under field conditions also significant variation was shown among the provenances except for mean daily germination and germination value. Germination percentage was superior for Indukki provenance and was comparable with Wyanad provenance.
5. Trivandrum, Kollam and Wyanad provenances were superior with respect to height growth but quicker radial expansion were registered by the Trivandrum and Idukki provenances.

6. With respect to the number of leaves per plant, except 120 and 240 DAS no significant variation was shown among the provenances. There was a reduction in the number of leaves per plant during 240 DAS and maximum number of leaves was superior for the Wyanad provenance.
7. Higher leaf area which resulted in high growth rate was found to be superior in the Idukki and Wyanad provenances.
8. Root growth pattern showed significant variation among the provenances and Trivandrum and Kollam registered higher mean values during initial stages of growth and to the later stages Wyanad and Idukki were showing superior performance.
9. Presence of number of lateral roots and physiologically active lateral roots per plant showed significant variation and Trivandrum, Kollam, Idukki and Wyanad were comparable at different stages of growth.
10. Biomass production with respect to leaf, stem, root and shoot dry weight were affected among the provenances Wynand, Idukki and Kollam were superior for all the above characters, which was the result of effective utilization of solar radiation.
11. The provenances did not show marked variation with respect to specific leaf area and root-shoot ratio.
12. Relative growth rate performance was superior for Trivandrum, Kollam and Idukki and for net assimilation rate significant variation was shown only at 300 DAS and the highest mean value was registered for Kollam provenance.
13. Relative water content, one of the physiological parameter of the rosewood provenance showed significant variation during the initial and later stages of the growth period. After the dry spell also, the RWC showed a decline, which indicates that the RWC is considered as a character of stress intolerant species.
14. Chlorophyll content which greatly influences the growth of the individual did not show significant variation at any of the experimental period.

The above results lead to the following conclusions. The rosewood seedlings showed significant variation among the provenances, for most of the characters studied. Among the five provenances tested, i.e., Wynad and Idukki provenances were found to perform superior with respect to germination, biomass and biometric characters. But for seed characters, relative growth rate and net assimilation rate Trivandrum and Kollam provenances were performing superior. So by further scientific studies, more details about the variations of these provenances can be understood. So from the present investigation it can be presumed that, as Wyanad and Idukki provenances were statistically superior performers, they can be considered as genotypically superior compared to the others and Thrissur (local provenance) which registered the least values for most of the significant characters as genotypically poor performer.

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* Orginals not seen.

APPENDICES

Appendix I. Weather parameters during the study period

Month	Weather parameters				
	Mean monthly temperature (°C)		Meam monthly Rainfall (mm)	Number of rainy days	Relative humidity (%)
	Maximum	Minimum			
June	29.4	23.0	500.2	24	84.5
July	28.4	23.0	823.3	28	89.0
August	29.8	22.9	260.1	18	83.5
September	31.6	23.4	28.4	24	72.0
October	30.5	23.2	506.2	12	89.5
November	31.4	22.7	9.1	9	69.0
December	30.7	22.7	0.0	4	60.0
January	32.9	23.2	0.0	0	59.5
February	33.3	22.8	4.6	1	78.0
March	35.6	23.9	0.0	0	66.5
April	34.0	24.6	67.9	3	74.0
May	33.3	24.4	117.2	8	77.0

Source: Department of Agricultural Meteorology, College of Horticulture, Vellanikkara

Appendix II. Details of the locality factors of *Dalbergia latifolia* provenances

Provenance	Longitude	Latitude	Altitude above MSL (m)	Temperature (°C)	Rainfall (mm)
Trivandrum	76° 55'E	8° 29' N	30	28.8	2203
Kollam	76° 36' N	8° 53' N	3	27.3	2561
Thrissur	76° 13' E	10° 31' N	22	30.7	3263
Wyanad	76° 1' E	11° 48' N	26	26.3	3590
Idukki	77° 10' E	9° 35' N	27	24.5	3377

Appendix-III. Abstract of Anova tables for Individual seed characters

Source	Degrees of freedom	Mean squares				
		Seed length (cm)	Seed breadth (mm)	Seed thickness (mm)	Individual seed weight (g)	100 seed weight (g)
Replication	3	0.862	0.381	0.019	0.006	0.048
Provenance	4	0.117	0.426	0.007	*0.003	*0.215
Error	12	0.473	0.528	0.032	0.002	0.027
Total	19					

Appendix-IV.Abstract of Anova tables for germination characters in the laboratory

Source	Degrees of freedom	Mean squares				
		Germination %	Germination completion	Peak value	Germination value	Mean daily germination
Replication	3	9.100	0.340	1.300	10.560	0.340
Provenance	4	*12.800	2.840	*2.300	*126.960	*2.840
Error	12	3.400	1.115	1.100	32.710	1.115
Total	19					

Appendix-V.Abstract of Anova tables for germination characters in the field

Source	Degrees of freedom	Mean squares				
		Germination %	Germination completion	Peak value	Mean daily germination	Germination value
Replication	3	20.183	6.933	1.933	0.317	50.733
Provenance	4	*4925.685	*23.125	*3.200	0.575	85.950
Error	12	57.808	4.892	1.600	0.775	66.983
Total	19					

Appendix-VI. Abstract of Anova tables for shoot height

Source	Degrees of freedom	Mean squares					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Replication	3	3.545	8.721	5.709	6.618	34.033	56.729
Provenance	4	*24.408	4.680	13.042	*31.503	*116.906	*127.372
Error	12	5.319	4.477	9.255	8.310	21.070	22.959
Total	19						

*Significant at 5% level

Appendix-VII. Abstract of Anova tables for collar diameter

Source	Degrees of freedom	Mean squares					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Replication	3	0.043	0.004	0.029	0.338	0.526	0.333
Provenance	4	*0.146	*0.732	*1.243	0.519	*2.728	*3.843
Error	12	0.086	0.103	0.116	0.312	0.643	0.692
Total	19						

Appendix-VIII. Abstract of Anova tables for leaves/seedlings

Source	Degrees of freedom	Mean squares					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Replication	3	8.761	27.614	9.830	34.787	55.380	30.669
Provenance	4	9.333	*49.949	7.268	*461.621	15.257	151.587
Error	12	7.648	32.622	17.730	60.997	8.336	130.538
Total	19						

Appendix-IX. Abstract of Anova tables for leaf area

Source	Degrees of freedom	Mean squares					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Replication	3	933.113	1655.243	908.193	1468.706	272.051	1330.677
Provenance	4	2430.010	2100.669	6593.252	*15530.096	*1645.713	*22032.136
Error	12	2126.147	3139.787	4960.730	6524.492	285.246	6544.929
Total	19						

Appendix-X. Abstract of Anova tables for root length

Source	Degrees of freedom	Mean squares					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Replication	3	0.631	11.887	4.865	9.504	3.894	28.089
Provenance	4	3.386	*12.174	*17.956	*48.003	35.239	*40.978
Error	12	2.213	2.521	6.772	6.714	22.777	7.302
Total	19						

*Significant at 5% level

Appendix-XI. Abstract of Anova tables for lateral roots

Source	Degrees of freedom	Mean squares					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Replication	3	0.181	0.126	0.087	0.273	0.082	0.125
Provenance	4	*2.743	*0.809	0.141	0.159	*0.261	*0.184
Error	12	0.116	0.396	0.083	0.163	0.131	0.127
Total	19						

Appendix-XII. Abstract of Anova tables for fresh lateral roots

Source	Degrees of freedom	Mean squares					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Replication	3	0.295	1.019	6.420	3.359	5.244	8.814
Provenance	4	0.862	3.914	*13.748	*22.732	4.334	8.098
Error	12	0.513	2.151	5.372	4.500	5.468	4.925
Total	19						

Appendix-XIII. Abstract of Anova tables for stem dry weight

Source	Degrees of freedom	Mean squares					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Replication	3	0.012	0.005	0.008	0.033	0.015	0.087
Provenance	4	*0.025	0.024	0.018	0.115	*0.112	*0.092
Error	12	0.006	0.019	0.012	0.515	0.023	0.025
Total	19						

Appendix-XIV. Abstract of Anova tables for leaf dry weight

Source	Degrees of freedom	Mean squares					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Replication	3	0.039	0.018	0.019	0.339	0.000	0.066
Provenance	4	*0.061	*0.085	*0.142	0.096	0.002	*0.126
Error	12	0.017	0.013	0.017	0.104	0.001	0.072
Total	19						

*Significant at 5% level

Appendix-XV. Abstract of Anova tables for specific leaf area

Source	Degrees of freedom	Mean squares					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Replication	3	35841.720	25885.605	36566.686	127483.032	523671.305	25770.031
Provenance	4	*66618.268	*90350.318	*188764.787	67804.092	*4560381.009	20679.603
Error	12	18210.918	11267.838	52326.108	74744.396	2169885.749	28871.960
Total	19						

Appendix-XVI. Abstract of Anova tables for shoot dry weight

Source	Degrees of freedom	Mean squares					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Replication	3	0.081	0.004	0.034	0.546	0.013	0.084
Provenance	4	*0.154	*0.136	*0.233	0.211	*0.107	*0.156
Error	12	0.036	0.013	0.029	0.253	0.023	0.095
Total	19						

Appendix-XVII. Abstract of Anova tables for root dry weight

Source	Degrees of freedom	Mean squares					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Replication	3	0.008	0.007	0.023	0.017	0.004	0.030
Provenance	4	*0.015	0.006	*0.029	0.019	0.036	0.028
Error	12	0.010	0.017	0.010	0.049	0.034	0.031
Total	19						

Appendix-XVIII. Abstract of Anova tables for root shoot ratio

Source	Degrees of freedom	Mean squares					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Replication	3	0.004	0.008	0.041	0.053	0.055	0.043
Provenance	4	0.027	0.015	0.012	0.007	0.067	0.059
Error	12	0.014	0.020	0.014	0.012	0.121	0.034
Total	19						

*Significant at 5% level

Appendix-XIX. Abstract of Anova tables for relative growth rate

Source	Degrees of freedom	Mean squares					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Replication	3	-	0.002	0.001	0.002	0.001	0.008
Provenance	4	-	*0.001	*0.001	*0.002	*0.002	*0.008
Error	12	-	0.001	0.001	0.001	0.001	0.004
Total	19						

Appendix XX. Abstract of Anova tables for net assimilation rate

Source	Degrees of freedom	Mean squares					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Replication	3	-	0.002	0.001	0.010	0.010	0.001
Provenance	4	-	0.001	0.001	0.002	*0.020	0.001
Error	12	-	0.001	0.001	0.001	0.001	0.001
Total	19						

Appendix-XXI. Abstract of Anova tables for relative water content

Source	Degrees of freedom	Mean squares					
		60 DAS	120 DAS	180 DAS	240 DAS	300 DAS	360 DAS
Replication	3	0.000	0.001	0.001	0.000	0.002	0.014
Provenance	4	*0.001	0.001	0.002	0.003	*0.010	*0.026
Error	12	0.000	0.018	0.002	0.002	0.001	0.006
Total	19						

Appendix-XXII. Abstract of Anova tables for chlorophyll A

Source	Degree of freedom	Mean squares		
		120	340	360
Replication	3	0.069	0.080	0.022
Provenance	4	0.146	0.096	0.048
Error	12	0.089	0.053	0.039
Total	19			

*Significant at 5% level

Appendix-XXIII. Abstract of Anova tables for chlorophyll B

Source	Degree of freedom	Mean squares		
		120	240	360
Replication	3	0.015	0.033	0.003
Provenance	4	0.013	0.119	0.094
Error	12	0.029	0.077	0.081
Total	19			

Appendix-XXIV. Abstract of Anova tables for total chlorophyll

Source	Degree of freedom	Mean squares		
		120	240	360
Replication	3	0.067	0.078	0.038
Provenance	4	0.112	0.287	0.260
Error	12	0.197	0.200	0.226
Total	19			

EVALUATION OF PROVENANCES FOR SEEDLING ATTRIBUTES IN ROSEWOOD

(Dalbergia latifolia Roxb.)

By

RESMI NAIR R.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

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ABSTRACT

A randomised block design experiment involving the performance of selected provenances, i.e., Trivandrum, Kollam, Wyanad, Idukki and Thrissur (local provenance) of *Dalbergia latifolia* Roxb. initiated during June 1999 was used for the present investigation. This study was undertaken to examine the seed characteristics, germination characters, growth parameters and physiological characters.

Seed characteristics like 100 seed weight and individual seed weight showed significant variation among the provenances. The seeds from Trivandrum provenance was found to be superior than the others. Idukki registered the lowest mean value for the individual seed weight and the others were on par. Germination behaviour of rosewood provenances in the laboratory conditions showed significant variation except in the case of days taken to complete germination. Wyanad provenance recorded the highest germination percentage and other germination characters like peak value, mean daily germination and germination value were superior for Idukki provenance and it was statistically comparable with the Kollam provenance. Except mean daily germination and germination value, significant variation was shown by the provenances with respect to the germination characters in the field conditions. Idukki provenance was superior with respect to germination percentage and was on par with Wyanad provenance. Inferior performance in the case of peak value was shown by Thrissur (local provenance) and the others were comparable. More time for completion of germination was taken by Kollam which was having a statistically inferior germination percentage.

Biometric observations also showed significant varition among the provenances except leaf area. At 60 DAS Trivandrum and Kollam were superior over the others for shoot height. Wyanad and Idukki which registered the least values at 60 DAS were superior towards the later stages of growth. Statistically inferior performance was shown by local provenance at all stages of the

experimental period. For root length and collar diameter also similar trend was followed. With respect to number of leaves per plant superior performance was registered by the Wyanad provenance, but for leaf area both Wyanad and Idukki performed better. Trivandrum, Wyanad and Kollam provenances were comparable for the number of lateral roots and physiologically active fresh lateral roots were superior for Trivandrum and Idukki provenances.

Biomass production which plays an important role in the ultimate biological yield, showed significant variation among the provenances. Kollam, Wyanad and Idukki provenances were statistically superior for various biomass characters such as stem, leaf, root and shoot dry weight.

Physiological parameters like relative growth rate and net assimilation rate showed significant variation among the provenances. Idukki, Kollam and Trivandrum were superior with respect to relative growth rate and Kollam registered the highest mean for the net assimilation rate which was on par with Wyanad and Idukki provenances. Chlorophyll content, which decides the photosynthetic potential in plants did not show any significant difference among the provenances throughout the experimental period.