EFFECT OF SHADE LEVELS ON GROWTH AND VIGOUR OF SEEDLINGS OF *TERMINALIA* SPECIES IN THE NURSERY

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DEPARTMENT OF TREE PHYSIOLOGY AND BREEDING

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2002

DECLARATION

I hereby declare that the thesis entitled **"Effect of shade levels on growth and vigour of seedlings of *Terminalia* species in the nursery"** is a bonafide research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any University or Society.

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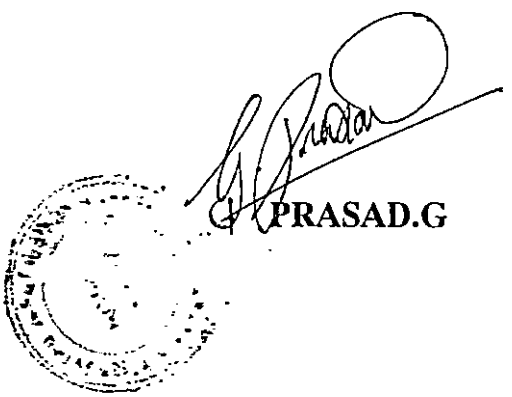

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DEDICATED TO THE
LOVE OF MY
PARENTS

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Introduction

INTRODUCTION

Sunlight is one of the most important factors, sustaining life on the planet by providing energy which is assimilated by green plants. These primary produces keep the web of ecological systems functional. Man has been depending on plants not only for food but also for fuel, timber, fodder, medicines and many other raw materials in his day to day life.

Sunlight plays the key role in the physiology of plants, their growth and phenology. The requirement of sunlight varies according to species and their growing conditions. Selection of the best species for a particular system calls for an accurate knowledge of the light availability of various species under varying light regimes. This knowledge is essential in making judicious selection of species suited for different situations.

The productivity of a forest ecosystem, where trees account for substantial amount of total biomass is greatly depended on sun light. It has been established by some workers that the availability of sunlight and nitrogen limits the rate of woody plant growth in forest under storey. Interspecific differences in the growth responses of saplings to the availability of these resources could affect the species composition of forest communities. There exists a clear relationship between forest dynamics and light availability that have accounted for 21 to 79 per cent of variation in sapling growth of a forest as is evident from many studies done by researchers.

Most of the silvicultural operations like thinning, spacing, crown density, plot protection, felling etc. have their impact on light availability in natural ecosystems. A rigorous observation is needed to understand the effect of these

treatments on light availability which may in-turn decide the species density and structure of the forest ecosystems.

Knowledge of light requirement of a species is desirable and in some cases becomes important in planning the spacing in young plantations and subsequently other silvicultural operations as said before. All this has profound influence on the requirement of irrigation, fertilizer application, protection and other considerations in a plantation.

Any of the ecorestoration and afforestation works need an immense knowledge of light activated behaviour of the various species. Light is therefore considered from the choice of species to the sustenance and regeneration of the crop for which the forester must have a close experience with the habit of the species used. Another factor to be considered in plantations is the nature of growth of the plant species as influenced by light. Various parts of the plant or physiological processes like leaf production, flowering, seed or fruit production, root production, oil content, pigment content, disease and pest resistance etc. respond differentially to light. So, depending upon the end use of the plant, the conditions in which it has to be raised also varies. Optimal levels of light for maximizing production of each component must be adhered to in each case.

Terminalias (Laurels) are major trees belonging to the family Combretaceae, occupying large areas of forests in our country, particularly in Kerala. They are frequently met within the deciduous forests, which form the major chunk of the Indian forests. These trees are known for their thin, straight bole and crown, giving them the name laurels. Many members including the species studied are commercial timer species of the tropics. Others have remarkable medicinal uses. These trees are also prominent members of our

homestead garden and other ecorestorational programmes. Hence the present study was conducted to evaluate the effect of various shade levels on the growth and vigour of seedlings of tembavu [*Terminalia tomentosa* var. *crenulata* (Roth. Cl.)] thanni [*T. bellirica* (Gaertn.) Roxb.] and neermaruthu [*T. arjuna* (Roxb. ex. DC.) Wt. & Arn.] in the nursery. The information going to be generated from the present study could be used for screening of the species based on their light requirement. This knowledge is very essential for the large scale planting programmes of Terminalias.

Review of Literature

REVIEW OF LITERATURE

Sunlight is the primary source of energy for all life activities and hence, all living beings depend on sunlight for their sustenance, either directly or indirectly. The green plants fix carbondioxide in the form of soluble carbohydrates in the presence of water and sunlight. This is the basis of dry matter production. Requirement of sunlight varies between different species of plants. However, it is a well established fact that sunlight is the prime factor determining the physiological activities and growth of plants. The intensity, duration and amount of light falling on earth vary greatly. The degree of shade is a key determinant of light related functions of the plant body. Number of studies was conducted on the effect of various levels of shade on the growth and productivity of plants, like vegetables and ornamentals. However, such studies are scanty in tropical tree species, particularly Terminalias that are very important for timber production and also for extensive planting under agroforestry and social forestry programmes in the state.

Terminalias (Laurels) are important components of the deciduous forests of our country, which form the major chunk of the forests in India (Troup, 1846). Timber of commerce is obtained from *Terminalia tomentosa* var. *crenulata*. Fruits of *Terminalia bellerica* and bark of *Terminalia arjuna* are constituents of various ayurvedic drugs. All these species can also be grown in homesteads of Kerala.

2.1 Effect of shade on growth of shoot

Fairbarian and Neustein (1970) reported that seedlings of six species of *Ricea sitchensis*, *Pseudotsuga menziesii*, *Tsuga heterophylla*, *Abies grandis*, *Picea*

abies and *Abies alba* showed highest shoot length when grown under 50 per cent shade. However, collar diameter, ratio of collar diameter to shoot length and total dry weight showed highest values when grown under full sunlight. In *Casuarina equisetifolia*, height of seedlings was reported to be unaffected by shading, but dry weight was maximum in full sunlight (Shafiq *et. al.*, 1974).

Seedlings of *Pinus sylvestris, P. nigra, Tilia tomentosa, Acer pseudoplatanus, Quercus petraea* and *Fagus sylvatica* when grown in 100, 50, 25 and 12.5 per cent of full sun light upto a period of eight years showed that except *Tilia tomentosa*, all other species produced greater aerial biomass under full sunlight, whereas *T. tomentosa* performed well under 50 per cent shade (Lyapova and Palashev, 1982).

Rao and Singh (1985) has reported that seedling growth of *Pinus roxburghii* and *Quercus butrichopleorea* when grown under 100, 70, 50 and 18 per cent sunlight showed that *P. roxburghii* was less tolerant to shade. Studies on the effect of shade on seedlings of *Shorea almon, Parashorea malanonan, Anlsoptera thurifera, Shorea polyspermum, Hopea parviflora* and *Vatica mangachopi* indicated that in all the species, maximum growth in height, diameter and dry weight was observed when plants were grown in full sunlight (Suzuki and Jacaline, 1986).

Bush and Auken (1987) showed that light intensity had substantial relationship with the growth of aerial parts of plants especially at seedling stage of *Prosopis glandulosa*. Light intensity increased stem length, dry weight and basal diameter of the seedlings. In seedlings of *Pinus sibirica*, decrease in illumination lead

to a reduction in the diameter growth and number of side shoots (Yushkow and Zav'yalova, 1988).

The seedlings of *Platanus orientalis, Sorbus torminalis* and *Corylus avelana* were grown under 50, 25 and 12.5 per cent shade along with full sunlight. *Platanus orientalis* performed best in full sunlight with respect to height diameter and biomass, while *S. torminalis* did best at 50 per cent light and *C. avelana* in both 50 and 25 per cent light (Lyapova and Palashev, 1988).

In the seedlings of *Pinus contorta*, simulated shade was found to increase tracheid number and diameter and wall thickness of xylem and phloem. These were all anatomical modifications caused due to shade (Caesar, 1990). Orians (1991) studied the response of *Inga oerstediana* grown under three different light environments viz., the under story, tree fall gap and full sunlight. Growth of the plant was found to be better when grown under full sunlight compared to other situations. The three evergreen conifers *Abies scholinensis, Picea jenfonensis* and *P. glehnii,* showed variations in tolerance to shade levels. Ability to tolerate shade stress was higher for *A. schalinensisi* compared to *Picea* sp. (Tujimoto and Shimada, 1991).

Responses of shade on growth of Douglas fir (*Pseudotsuga menziesii*), Western Hemlock (*Tsuga heterophylla*) and Western Red Cedar (*Thuja plicatus*) was studied by Carter (1992) and found that Western Red Cedar performed better at lower light levels compared to other species.

Quercus lobata, Q. douglasii and *Q. agrifolia* were grown under different shade levels and full sunlight. No variations were noticed in growth with regard to different shade levels. In *Q. lobata* and *Q. douglasii* shade did not affect the seedling

biomass (Callaway, 1992). Cornelissen (1992) studied the growth of *Gordomia acuminata* grown under four shade levels (55%, 33%, 18% and 0%). Best growth was noticed at 33 per cent shade. Studies done by Oscinkoya and Ash (1992) with six species at 37, 10 and 2.5 per cent shades showed the positive effect of 37 per cent shade on shoot growth of all the species.

Seedlings of *Azadirachta indica* recorded more height and collar diameter under open conditions, while seedlings of *Leucaena leucocephala* recorded more girth when grown under 25 and 50 per cent shade levels. However, height was more when *L. leucocephala* was grown under 25 per cent shade (Vimal, 1993). Cregg and Teskey (1993) in loblolly pine observed a reduction in growth in the shaded seedlings. Studies using seedlings of *Pinus brutia, Cupressus sempervirens* and *Casuarina equisetifolia* has shown that in *P. brutia*, plant height and weight of branches were greatest and number of branches least when grown under 25 per cent shade. However, in *Cupressus sempervirens* maximum plant height, weight and number of branches were produced under 75 per cent shade.

Sharma *et al.* (1994) conducted a study on the growth behaviour of *Enicostemma littorale*, a medicinal plant grown under full light and shade conditions. Vegetative growth attributes including height, fresh weight, dry weight, number of leaves and number of branches was enhanced when grown under shade compared to full sunlight. However, flower production was found to be reduced due to shade. The effect of shade on seedlings of *Dalbergia sisso, Acacia catechu* and *Casuarina equisetifolia* were studied under nursery conditions in Uttar Pradesh (Saxena *et al.*, 1995). Artificial shade was provided by using varying layers of musilin clothes.

Growth of *D. sisso* and *A. catechu* was maximum when grown under low shade condition while *C. equisetifolia* showed maximum growth in unshaded conditions. Root/shoot ratio was found to be lowest in *C. equisetifolia.* In all the species, increment in height and stem diameter per unit dry weight was greater when grown under higher shade conditions.

Barizan *et al.* (1996) studied the growth and survival of *Hopea odorata* grown under different light conditions and fertilizer levels in Malaysia. Three different conditions were selected viz., open area with compacted soil (80-100% of opening), a partially shaded gap with less compacted soil (30-60% opening) and closed canopy areas, not subjected to silvicultural treatments. The mean growth of seedlings in terms of height and girth was significantly better under first and third situations. The height increment of seedlings under the third condition was very low compared to the others.

In *Phyllanthus stipulatus* the plant height was found to be higher when grown under 30 per cent shade than in sun in a study done in Brazil (Silva *et al.*, 1997). The effect of light quality on the growth and flowering of Chrysanthemum cultivars under glass house conditions provided with three different colour filters indicated the plant height was significantly affected by light quality and temperature. The plant height was found to be regulated by the action of both phytochrome and a blue acting photoreceptor (Khattak *et. al.*, 1997).

A study done to find out the effect of shade (0, 55 and 95%) on *Hibiscus syriacus* L. in Korea showed that the shoot lengths of most of the cultivars were longer in shade grown plants compared to control plants. Two cultivars showed a reduction in height compared to control plants. However, shoot dry weights under 95 per cent

shade, compared to control plants, did not show any substantial variations. But there was a reduction of root dry weight in some cultivars (Yoo and Kim, 1997).

Alphalo and Lehto (1997) studied the effect of quality of light on the growth of birch seedlings. During the first 15 days, largest effect of light was on height growth, which was greater for seedlings grown in simulated shade light. During this period, light quality was found to have little effect on dry weight and nitrogen allocation to stem.

In British Columbia, Chen (1997) studied interspecific responses of planted seedlings to light availability. The study revealed that with decreasing light availability, survival of *Pseudotsuga menziesii* and *Picea engelmannii* seedlings did not change unlike *Pinus ponderosa* seedlings where survival rate reduced significantly. The seedlings of *Picea engelmannii* recorded maximum reduction in height growth, while *P. menziesii* recorded maximum reduction in diameter growth with decreasing light. Height-diameter ratio remained almost constant in *P. ponderosa*. They also observed that morphological characters were more plastic in shade tolerant species.

Growth of *Cryptocaria aschersoniana* seedlings under different light regimes viz.; 0, 50, 70 and 90 per cent in the nursery was studied by Rezende *et al.* (1998). Maximum height growth was recorded for 90 per cent shade followed by 50 per cent shade. More or less similar trend was noticed with regard to collar diameter also. Williams *et al.* (1999) found that the shade tolerance of Douglas fir (*Pseudotsuga menziesii*) and Lodgepole pine (*Pinus contorta*) was found to be more when grown in dry sites compared to moist sites.

The seedlings of *Grevillea robusta, Tectona grandis* and *Ailanthus triphya* were grown under varying shade conditions and full light. Seedlings of *G. robusta* and *T. grandis* performed well under full sunlight, while *Ailanthus triphya* performed well under 75 per cent shade with regard to stem height, diameter and shoot dry weight (Saju *et al.*, 2000). The leaf and root growth parameters were also found to be influenced by shade.

2.2 Effect of shade on leaf growth parameters

Wadsworth and Lawton (1968) conducted studies on the effect of shade in *Pinus carieba, Eucalyptus deglupta* and *Khaya grandifolia* seedlings and reported an increase in leaf area ratio with increase in shade. In maple and aspen, increase in shade reduced the leaf thickness while number of layers and length of palisade cells increased in the intercellular spaces in spongy parenchyma. However, in oak and birch shading had less marked effect on structure and thickness of leaf (Malkina and Kovalev, 1973). Scifres *et al.* (1973) reported that increase in shading decreased leaf area of seedlings of *Prosopis glandulosa.* In *Betula pendula* and *B. pubescens* seedlings, shading was found to increase the specific leaf area with a decrease in leaf mesophyll thickness and amount of chlorophyll per unit area of leaf (Nygren and Kellomaki, 1983).

Masarovicova (1985) reported that *Fagus sylvatica* grown under different shade levels showed an increase in average leaf area, specific leaf area and leaf mass with increased light intensity. In seedlings of *Guarea gindimia,* larger leaves were produced in shade, but with thinner blades and lower specific weight (Fischer, 1986). Singh (1986) studied the effect of light intensity on growth and yield of rain fed cotton

and found that low irradiance increased the LAR, but decreased the relative growth rate, leaf area and net assimilation rate.

Studies by Bush and Auken (1987) using *Prosopis glandulosa* seedlings revealed that maximum leaf and leaf dry weight were produced as a result of full sunlight. In *Acacia tortilis*, leaf area ratio increased with decreasing light intensity (Smith, 1988). In *Betula pendula*, as PAR decreased, reduction in leaf extension was observed. However, in *Acer pseudoplantanus*, it had no effect (Taylor and Davies, 1988). Fitter and Ashmore (1989) found that *Veronica montana* seedlings were unaffected by supplementary far red radiation, while *V. persica* showed a reduction in leaf area in response to supplementary far-red radiation. *Shorea trapezifolia* seedlings showed no effect with regard to number of leaves when grown in partial shade or full sunlight (Ashton and Zoysa, 1989). Kim (1989) found that in *Pinus torainensis* seedlings, growth in leaf area was most rapid at 63 per cent RLI and slowest at 19 per cent RLI. Hazra (1989) reported that there was an increase in the leaf production in pulses, for plants exposed to sunlight when compared to those under tree canopy. The seedlings of *Northofagus procera* when grown under partial shade resulted in the production of less number of leaves (Igboanugo, 1990).

Allard *et. al.* (1991) reported an increase in leaf area under shade in tall fescne grass. Low irradiance was found to increase the leaf area ratio, but decreased the relative growth rate and net assimilation rate. Callaway (1992) studied the changes in leaf area of *Quercus lobata, Q. douglasii* and *Q. agrifolia* seedlings when grown under 10 per cent 30 per cent and 100 per cent sunlight. Total leaf area of *Q. lobata*

and *Q. douglasii* did not increase due to shade, whereas at 10 per cent shade, *Q. agrifolia* seedlings produced greater leaf area.

Kuapp (1992) studied the rate of net photosynthesis, stomatal conductance to water vapor and leaf xylem pressure potential of deciduous *Quercus macrocarpa* when grown under attenuating periods of sun and shade. Photosynthesis was found to be high under full sun while stomatal conductance to water vapour was higher in shade.

Potted seedlings of *Acacia mangium*, *A. auriculiformis* and *A. mearnsii* were grown under different shade condition. Leaf area was reported to be in maximum in *A. mearnsii* and least in *A. auriculiformis* due to shade. The chlorophyll ratios were found to be reduced, with decrease in light levels (Lovelock, 1992). In *Pongamia pinnata*, the leaf area was found to be increased due to increase in shade (Naidu and Swami, 1993). *Ailanthus triphysa* and *Leucaena leucocephala* seedlings showed maximum leaf weight under 25 per cent shade while *Azadirachta indica* showed maximum under 50 per cent shade (Vimal, 1993).

Sharma *et al.* (1994) studied the growth behaviour of *Enicostemma littorale* grown under light and shade conditions. The number of leaves and branches was enhanced when grown under shade compared to full sunlight. Mc Kendrick (1996) studied the influence of different photosynthetic photon fluence rates (PPFR) of 24, 54 and 225 μ mol m^{-2} s^{-1} on the British orchids namely *Orchis morio* and *Dactylorhiza fuchsii* and also on dicotyledonous perennial *Leontodon hispidus*. Orchids tolerated more shade than *L. hispidus*. A decrease in PPFR caused a decrease

in dry weight and an increase in specific leaf area. Growth of *L. hispidus* was found to be affected by reduction in PPFR compared to orchids.

Gross *et al.* (1996) has reported the effect of shade on stomatal conductance, net photosynthesis, photochemical efficiency and growth of oak saplings in relation to full and 50 per cent sunlight. Stomatal conductance and photosynthesis were found to be increased in open field while shaded plants produced larger leaves with fewer stomata per unit leaf area. The chlorophyll content was also found higher under shade.

Studies on seedling development under varying photon flux density (PFD) and spectral quality (red to far red) along with various shade levels of 40, 12 and 3 per cent PFD revealed that total height, internode distance, stem length, leaf area, percentage allocation to leaf, stem and root mass, specific leaf mass, mean leaf area and stomatal density were dependent on light intensity (Lee *et al.*, 1996).

Influence of shade on specific leaf weight, leaf thickness and internal structure of leaves of *Euonymus japonicus* cv. Luna was studied by Hosni and Shehata (1996) in Egypt. Compared to control, shade increased leaf area with reduced leaf thickness per leaf. Leaf fresh weight was found to be reduced, when grown under 65 per cent shade. The specific leaf weight was also reduced by shading. Moreover shading reduced the thickness of palisade layer by 37 to 45 per cent.

Production of pigment proline, protein and polyamines in *Aloe arborescence, A. saponaria* and *A. vera* grown under sunlight and shade was studied by Lee *et al.* (1996). Plants grown in open field under full sunlight contained more chlorophyll than those grown in shade. *Aloe arborescence* and *A. saponaria* when

grown under shade was found to contain less anthocyanins and carotenoids than those grown in open sun light. The proline, protein and polyamine contents of *A. arborescence* and *A. saponaria* decreased due to shade. However, the shade was not having any effect on *A. vera* with regard to above parameters.

Hampson *et. al.* (1996) conducted a study to quantify the effect of shade on reproduction and photosynthetic rate in seedlings of hazelnut, a shade tolerant species. Plants were grown under 30, 47, 63 73 and 92 per cent shade levels. Leaf area increased by 49 per cent and chlorophyll concentration by 157 per cent as shading increased from 0 to 92 per cent. The 92 per cent shading treatment reduced specific leaf weight, stomatal density and light compensation point compared to the control. Grubb *et al.* (1996) studied the interaction of irradiance and soil nutrient supply on growth of F*agus sylvatica* and *Juniperus comnunis. Fagus sylvatica* responded moderately to irradiance and not to nutrient supply. In shade, allocation of nutrients to roots decreased while that to stem and leaves increased. In all the species, shade was found negatively affecting the number of leaves, total leaf area, and shoot and root length.

Studies on chlorophyll content, nitrogen and non structural carbohydrates in leaves with a natural light gradient in *Acer platanoides, Padus avium, Populus tremula* and *Quercus robur* seedlings showed that leaf dry mass per area increased linearly with increasing relative irradiance. Decreasing irradiance enhanced chlorophyll per leaf dry mass. Average nitrogen content per mass increased and maximum concentrations of leaf nitrogen shifted towards more open habitats with decreasing shade tolerance. More tolerant species recorded greater concentration of

foliar nitrogen at low irradiance. The leaf nitrogen concentration in relation to irradiance was found to play a central role in shade tolerance of species (Niinemets, 1997). A functional relationship was proposed between leaf area, shade tolerance and light availability of tree species by (Raulier and Ung, 1997).

Nam *et al.* (1997) studied the effect of shade (0, 50, 80 or 95%) on chlorophyll content and degree of variegation of *Epipremnum aureum* and *E. aureum* (cv. Lime).Chlorophyll content in variegated plants was highest under 50 per cent shade, whereas in *E. aureum* (cv. Lime), highest chlorophyll content was noted under 80 per cent shade. Ratio between chlorophyll a and b decreased as light intensity increased. In variegated *E. aureum* 23 and 7 per cent of the leaf area was seen to be variegated respectively under 0 and 95 per cent shade. Number of variegated leaves also increased with increasing light intensity.

The effect of three levels of irradiance (100%, 56% and 33%) on carbon and nitrogen allocation in *Dicanthium aristatum* was studied in pot experiments under well watered and well fertilized conditions. Under 100 and 50 per cent of full sunlight, more N was allocated to the thicker shoot component. This situation was reversed in lowest radiation level, indicating that N reserves may limit the growth of this perennial grass under high levels of shade. A higher shoot to root ratio under shade was also noticed here (Cruz, 1998).

Shade was found to have no effect on dispersal, establishment and survival of *Ceriops tagal* propagules in North Australian mangrove forest (Mc Guinness, 1997). Studies on growth and nutrient uptake of *Dicanthium aristatum* grown in full sunlight or under tree shade with light transmission levels (ranging from 80-30% of

total PAR) were conducted by Cruz (1997). It was found that dry matter production and leaf area index were not depressed by reduction of incoming PAR. Johnston and Onwueme (1998) studied the effect of shade on the production of photosynthetic pigments in tropical root crops. Total chlorophyll concentration was higher while the chlorophyll a chlorophyll b ratio and carotenoides per unit area of leaf were lower under shade, compared to sun particularly with regard to *Dioscorea esculenta, Colocasia esculenta, Xanthosoma sagittifolium, Manihot esculenta* and *Ipomea batatas*. All the species produced larger leaves and more chlorophyll per leaf when grown under shade. Depending on shade tolerance their leaf size and weight also varied.

Studies done on some broad leaved trees and conifers revealed that more shade tolerant species generally possess a lower leaf area ratio. Leaf nitrogen content was generally lower in more shade tolerant broad-leafed species (Kerstiens, 1998).

Suk and Ja (1998) studied the growth and flowering of *Orostachys iwarenge* as influenced by day length and light intensity. Leaf width and leaf length increased more under short or intermediate photoperiods than under long day conditions. The number per plant increased significantly with increase in shade while leaf number decreased. In shade, leaf orientation turned downward as against upward orientation in full sunlight.

Mazzei *et al.* (1998) studied the growth of *Schefflera morototoni* seedlings in the nursery at 0, 50, 70 and 90 per cent shade. Seedlings grown under 0 per cent shade recorded the smallest average with regard to all growth parameter except for

root and shoot ratio which was smallest under 90 per cent shade. Generally, an intermediate shade was found most favourable for development.

Vyas and Nein (1999) studied the effect of shade on growth of *Cassia unguistifolia*. Shade was found to increase node number, leaf number, leaf area and length of internodes. The leaf area of plants exposed to shade also increased and followed the pattern similar to other growth parameters. The leaf stem ratio and leaf area ratio increased by 37.4 and 30.4 per cent respectively at 25 per cent shade compared to un shaded plants. Studies conducted at Vellanikkara revealed that in *Grevillea robusta* and *Tectona grandis* seedlings, shade reduced leaf area, leaf size and leaf dry weight (Saju *et al.*, 2000).

2.3 Effect of shade on growth of root

The growth and development of roots in relation to light availability was studied by many scientists. Seedlings of *Pinus dorsifolia* showed a reduction in root weight when grown under shade conditions (Negisi and Magi, 1986). The stem to shoot ratio of *Pinus koraiensis* were found to increase when grown under shade (Kim, 1987).

In *Pinus palustris* and *P. taeda* seedlings, root growth showed greatest response to light when grown in full sunlight conditions (Barmet, 1989). Burmeister and Auken (1989) reported an increase in number and weight of root nodules with increasing light intensity. Seedlings of *Leucaena leucocephala* and *Azadirachta indica* showed maximum dry root weight when grown in open and minimum when grown under 75 per cent shade. However, *Ailanthus triphysa* recorded maximum root dry weight under 25 per cent and minimum under full sunlight (Vimal, 1993).

Kung-Fang *et. al.* (1998) studied the root to shoot albometry and root architecture of understorey saplings grown in deciduous forests. Root to shoot ratio was found to be decreased rapidly with increasing plant height for saplings shorter than 1.5 m. Less shade tolerant species showed smaller root: shoot ratio. The planting depth was not significantly related to shade tolerance.

Influence of light on the growth of nine tree species was studied by Reich *et. al.* (1998). They found that under full sunlight conditions, the root length per unit plant mass (root length ratio, RLR) increased in all the species. The shade intolerant deciduous tree species showed higher RGR and specific root length (SRL), compared to evergreen species. Variations in interspecific relative growth rate (RGR) under high and low light intensities was found to be positively correlated with specific root length (SRL) and root length ratio (RLR).

A study was conducted to investigate the effect of different light conditions on germination and seedling growth of some selected forest tree species by Chathurvedi and Bajpai (1999) under three light conditions viz., semi shade, shade and full sunlight. The study revealed that root length was maximum under semi shady condition in *Bridelia retusa* and *Holarrhaena antidysenterica* while in *Lagerstroemia parviflora* and *Wrightia tinctoria*; it was maximum in full sunlight. Root: shoot ratio was highest under shady condition in *Holorrhena antidysenterica, L. parviflora* and *W. tinctoria*. The dry weight of root was found to be maximum when grown under full sunlight in *Grevillea robusta* and *Tectona grandis,* whereas *Ailanthus triphysa* seedlings recorded more root weight when grown under shade (Saju *et al.*, 2000).

2.4 Effect of shade on Biomass production and yield

Robert (1971) found that in red oak (*Quercus rubra* L.), the tallest seedlings grown under 30 per cent light recorded lowest dry matter production. Heavy shade lead to higher concentration of nutrients in foliage. *Quercus lobata, Q. douglasii* and *Q. agrifolia* were grown under different shade levels and full sunlight. No variation in biomass production with regard to shade levels was noticed in any of the species (Callaway, 1992). In *Casuarina equisetifolia*, height of seedlings was reported to be unaffected by shading but dry weight was maximum at full sunlight (Shafiq *et al.*, 1974).

Lyapova and Palashev (1982) studied the growth of seedlings of *Pinus sylvestris, P. nigra, Tilia tomentosa, Acer psuedoplatanus, Quercus petrae* and *Fagus sylvatica* grown under 100, 50, 25 and 12.5 per cent of full sunlight upto eight years. The study revealed that except *Tilia tomentosa*, all other species produced greater aerial biomass under full sunlight. *Tilia tomentosa* performed well under 50 per cent shade. Pathak *et al.* (1983) reported that *Leucaena leucocephala* seedlings raised under 45 per cent light conditions showed higher total dry matter production. Studies on the effect of shade on seedlings of *Shorea almon, Parashorea malanonan, Anlsoptera thurifera, Shorea polyspermum, Hopea parviflora* and *Vatica mangachopi* seedlings indicated that in all the species, maximum growth in height, diameter and dry weight was observed when plants were grown under full sunlight (Suzuki and Jacline, 1986). Bush and Auken (1987) showed that light intensity increased stem length, dry weight and basal diameter of seedlings of *Prosopis glandulosa*. In seedlings of *Pinus sibirica*, a decrease in illumination lead to reduction in diameter

growth and number of side shoots resulting more dry matter production (Yushkov and Zav'yalova, 1988).

The seedlings of *Platanus orientalis*, *Sorbus torminalis* and *Corylus avelana* were grown under 100, 50, 25 and 12.5 per cent of full sunlight. With regard to biomass production *S. torminalis* recorded maximum at 50 per cent light while *C. avelana* at both 50 and 25 per cent light (Lyapova and Palashev, 1988). Seedling biomass was seen unaffected due to shade in *Quercus agrifolia*, *Q. douglasii* and *Q. lobata* (Callaway, 1992).

Five day old seedlings of *Amphopterugium adstringens*, *Caesalpinia eriostachys*, *C. playtylotia*, *Apoplanesia paniculata* and *Helicarpus pollidus* were grown under two light treatments viz. high (400 µmol m^{-2} s^{-1}) and low(80µmol m^{-2} s^{-1}). In all the species, relative growth rate and net assimilation rate were greater when grown under high light treatments (Rincon and Huante, 1993). Effect of shade on physiology of *Coffea arabica* was studied by Aldazabal and Alarcon (1994). They found that fruits produced under shade condition were found to be larger than those produced were open sunlight. The time taken for fruit development was not affected by sunlight.

Leontodon hispidus, a perennial bush, showed reduced dry weight under low PPFR (photosynthetic photon fluence rates) while *Orchis morio* an orchid showed only slight reduction in dry weight due to low PPFR (Mc Kendrick, 1996).

Seedlings of *Betula peapyrifera*, *B. alleghaniensis*, *Ostrya virginiana*, *Acer saccharum* and *Quercus rubra* were grown to study the effects of light and nitrogen and their inter relationships on survival and growth. In very low light conditions,

greater growth and survival rates were shown by shade tolerant species, while shade intolerant species performed best under higher light conditions. They concluded that light requirement depends on species (Walters and Reich, 1996). Saxena *et. al.* (1995) reported that seedling growth of *Dalbergia sisso* and *Acacia catechu* was maximum under lower shade treatment, while *Casuarina equisetifolia* showed maximum growth in unshaded conditions. Root/shoot ratio was found to be lowest in *C. equisetifolia*. In all the species, production of stem dry matter was greater under higher shade conditions.

A study done to find out the effect of shade (0, 55 and 95%) on *Hibiscus syriacus* L. in Korea showed that the shoot lengths of three cultivars were longer in shade grown plants compared to control plants. However, compared to control, there was not much variation in dry matter production. There was also a reduction in root dry weight of some cultivars (Yoo and Kim, 1997).

Cruz (1997) studied the effect of shade on growth and mineral nutrition of *Dicanthium aristatum* seedlings grown under full sunlight and under *Gliricidia sepium* and *Leucaena leucocephala* with light transmission levels ranging from 80-30 per cent of insolation. Dry matter production was not found to be reduced by reduction in PAR.

Light quality had little effect on dry weight during initial stages as is evident from a study conducted by Alphalo and Lehto (1997) using silver birch (*Betula pendula*). However, at the end of the experiment, after 29 days, there was an increase in unit dry weight of leaves and stems of the seedlings along with high nutrient supply. The effect of organic manure on biomass production of *Phyllanthus stipulatus* showed that total plant biomass remains unchanged when grown under both

open and shade conditions (Silva *et al.*, 1997). Rezende *et al.* (1998) observed that *Cryptocaria aschersoniana* seedlings recorded more dry weight of roots, leaves and stems when grown under 50 per cent light conditions. Mazzei *et al.* (1998) also conducted similar studies in *Schefflera morototoni* seedlings, a shade loving plant. Intermediate (50-70%) shades were found to be best suited for this species with regard to all growth attributes. Vyas and Nein (1999) reported that increasing shade increased the dry matter accumulation in *Cassia unguistifolia.* Increase of leaf dry weight was more, when compared to that of stem.

Materials and Methods

MATERIALS AND METHODS

The present series of investigations were conducted at College of Forestry, Kerala Agricultural University, Vellanikkara, with an objective of studying the effect of different shade levels on the growth and vigour of seedlings of the following three species of Terminalias in the nursery.

i. Thembavu [*Terminalia tomentosa* var. *crenulata* (Roth.) Cl.]

ii. Thanni [*Terminalia bellirica* (Gaertn.) Roxb.]

iii. Neermaruthu [*Terminalia arjuna* (Roxb. ex DC.) Wt. & Arn.]

These three are commercial timber species of tropical deciduous forests and possess high medicinal properties. They are the chief constituents of the dry deciduous forests of the country (Troup, 1846) which form the major chunk of the Indian forests. They are also widely grown in homesteads of Kerala.

3.1 Location of the study

The College of Forestry, Kerala Agricultural University, Vellanikkara, comes under the Madakkathara panchayat of Thrissur district. The study area lies between 10°32' N latitude and 76°26' E longitude. The climate is warm humid with an average annual rainfall of 3,000 mm. The temperature variation during the day is not very wide. The soil is of lateritic origin. The area has an altitude of about 40 m above MSL. The mean maximum temperature ranged from 29°C (July) to 36°C (March) and mean minimum temperature from 22°C (January) to 24°C (April) during the study period.

3.2 Collection of seeds

Seeds of all the species were collected during the month of February to April from their reputed seed sources of the state. In the case of *T. arjuna*, seeds were collected directly from the healthy trees, while fallen seeds were collected in the case of *T. tomentosa* and *T. bellirica*. The seeds were then sun dried by spreading on cement floor for 3 to 4 days. Healthy, fully matured and cleaned seeds only were used for the study. Seeds were put in clean gunny bags and stored at ambient temperatures.

3.3 Raising seedlings for the study

Seeds were soaked in cold water for 24 hours prior to sowing to facilitate early and uniform germination. They were then sown in standard nursery beds of the size 12 m x 1.2 m x 0.3 m. The seeds were covered with a thin layer of sand after sowing.

One month old, uniform vigorous seedlings (Plates 1 to 3) were planted in 200 gauge polythene covers of 20 cm x 15 cm size filled with standard potting media containing soil, sand and well rotten cow dung prepared in 1:1:1 ratio. Before uprooting the seedlings, the nursery beds were watered so as to facilitate easy removal of the seedlings. The seedlings after planting in polythene covers were kept in shade for a week to overcome the transplantation shock. The established seedlings after one week were arranged in varying shade levels for taking the observations.

3.4 Providing shade

Artificial shade houses were made and shade was provided using nylon nets. The shade houses were constructed in the nursery towards the North South direction. The required shade levels were created by putting different layers of nylon

Plate 1. One month old seedlings of *Terminalia tomentosa* maintained in the nursery

Plate 2. One month old seedlings of *Terminalia bellirica* maintained in the nursery

Plate 3. One month old seedlings of Terminalia *arjuna* maintained in the nursery

nets. Shade levels were checked periodically by using quantum sensor. The following four shade levels were tested.

1. S_0 – 0 per cent relative shade (Full sunlight)
2. S_{25} – 25 per cent relative shade
3. S_{50} – 50 per cent relative shade
4. S_{75} – 75 per cent relative shade

3.5 Aftercare of seedlings

Watering of the seedlings was done daily. Weeding and necessary plant protection measures were also adopted periodically.

3.6 Experimental layout

The study was conducted in CRD with four shade levels and three species, each having three replications. The number of bags for each treatment was 100, making the total number of bags to 1,200 for the entire study.

3.7 Main items of observations

3.7.1 Shoot growth parameters

3.7.1.1 Height

The height of individual seedlings was measured from collar region to terminal bud at monthly interval using a meter scale.

3.7.1.2 Collar diameter

The collar diameter was measured using a digital vernier caliper at monthly interval..

3.7.1.3 Number of leaves

The number of leaves produced by individual seedlings was counted at monthly interval.

3.7.1.4 Leaf Area

Individual and total leaf area were measured at periodic interval and expressed as cm^2.

3.7.2 Stomatal frequency

Ten leaf samples per replication were collected representing each treatment for all the species and used to find out the stomatal frequency. A thin layer of quick fix was spread on the under surface of leaf and the membranous layer was peeled off carefully. The number of stomata per field was counted using a binocular microscope and stomatal frequency per square centimeter was estimated.

3.7.3 Root growth parameters

Destructive sampling was done at monthly interval and the following root observations were made.

3.7.3.1 Length of roots

Length of roots was measured from the collar region to the tip of the longest root and expressed in centimeter.

3.7.3.2 Spread of roots

Spread of roots was measured in both directions and average spread was worked out and expressed in centimeter.

3.7.4 Biomass production

3.7.4.1 Fresh weight of shoot and root

Representative seedlings were sampled from each treatment at monthly intervals for estimating the total biomass. The shoot and root portion of seedlings were separated and fresh weight was determined separately using precision balance.

3.7.4.2 Dry weight of shoot and root

The shoot and root portion of the samples were dried separately in hot air oven at a temperature of 80°C ± 5°C for about 24 to 48 hours. Dry weights were taken using a precession balance. The drying and weighing was repeated till constant weights were obtained.

3.7.5 Biochemical Analysis

3.7.5.1 Chlorophyll content

Chlorophyll content of the leaves was estimated following the method suggested by Staner and Hardley (1967). Two samples per replication were collected from all the treatments for estimating the chlorophyll content. Leaf samples collected from the experimental seedlings were cut into pieces and mixed. For estimating chlorophyll, 0.1 g of the sample was weighed and finely ground using a clean mortar, to extract the chlorophyll using 80 per cent acetone. The extract was filtered using Watman No.1 filter paper and made up to 25 ml using 80 per cent acetone. The absorbance was read at wavelengths of 663 nm and 645 nm using a spectrophotometer. The chlorophyll a, chlorophyll b and total chlorophyll content of each sample was calculated using the following formula

$$\text{Chlorophyll a (mg g}^{-1}\text{ of the tissue)} = \frac{V \times 12.7\,(\text{OD at } 663 \text{ nm}) - 2.69\,(\text{OD at } 645 \text{ nm})}{1000 \times W}$$

$$\text{Chlorophyll b (mg g}^{-1}\text{ of the tissue)} = \frac{V \times 22.9\,(\text{OD at } 645 \text{ nm}) - 4.68\,(\text{OD at } 663 \text{ nm})}{1000 \times W}$$

$$\text{Total chlorophyll (mg g}^{-1}\text{ of the tissue)} = \frac{V \times 20.2\,(\text{OD at } 645 \text{ nm}) + 8.02\,(\text{OD at } 663 \text{ nm})}{1000 \times W}$$

where, OD is the optical density

W is the fresh weight of the tissue in grams and,

V is the final volume of 80 per cent acetone extract.

3.7.6 Chemical analysis

Representative seedlings from each repications were taken for chemical analysis. The samples after drying were powdered. Fine powder was used for estimation of various nutrient elements. The following nutrients were analysed.

3.7.6.1 Nitrogen

Nitrogen content in dried samples was determined by digesting 0.1 g of the sample with 5 ml of concentrated sulphuric acid in the presence of 3 g of digestion mixture containing potassium sulphate and copper sulphate in 10:2 ratio. The digest

was distilled using 40 per cent NaOH. The ammonia titrated was absorbed in 4 per cent boric acid which was then titrated with 0.1 N sulphuric acid using mixed indicator (Jackson,1958).

3.7.6.2 Phosphorous

0.2 grams of the powdered sample was digested in triacid mixture (Nitric acid: sulphuric acid: perchloric acid in 10:1:3 ratio) and the digest was made up to 100 ml. A known quantity of aliquot was taken to determine the phosphorous content calorimetrically by the vanadomolybedo phosphoric yellow column method (Jackson, 1958). The colour intensity was read at a wavelength of 470 nm in UV spectrophotometer.

3.7.6.3 Potassium

The triacid extract prepared earlier was used to estimate potassium also. Potassium content was estimated in a digital flame photometer (Jackson, 1958).

3.8 Statistical analysis

Treatment means were analysed statistically using analysis of variance technique. The superiority of treatment means were tested using DMRT analysis.

Results

RESULTS

The present series of investigations were carried out in the College of Forestry, Kerala Agricultural University, Vellanikkara with an objective of finding out the effect of different shade levels on the growth and vigor of seedlings of *Terminalia* species in the nursery. The following species were included in the study

i. Thembavu [*Terminalia tomentosa* var. *crenulata* (Roth.) Cl.]

ii. Thanni [*Terminalia bellirica* (Gaertn.) Roxb.]

iii. Neermaruthu [*Terminalia arjuna* (Roxb. ex DC.) Wt. & Arn.]

The salient findings of the study are furnished below.

4.1 Effect of shade on shoot growth parameters

4.1.1 Height

The observations on the effect of shade on the height of seedlings of *Terminalia tomentosa* at monthly intervals are furnished in Table 1 and Figure 1. It is evident from the data that at the end of the study, i.e. after tenth month, the treatment T_3 (50% shade) recorded maximum height of 84.49 cm. which was followed by treatment T_1 (0% shade) where the height was 78.50 cm. The differences between the two treatments were not significant. The least height growth of 66.19 was noticed when seedlings were grown under 25 per cent shade. It could also be seen from the table that height growth was significantly influenced by shade levels during the second half of the study i.e., from the sixth month onwards. The effect of different shade levels on height was not significant from first to fifth month. However, the positive effects of 50 per cent shade on fast growth during the entire period of study are clearly evident from the data. The maximum total increment (60.05%) was recorded by T_3

Table 1. Effect of shade on height (cm) of seedlings of *Terminalia tomentosa* at monthly intervals

Treatment number	Treatment details	Age (months after planting)										Total increment
		1	2	3	4	5	6	7	8	9	10	
T1	0 per cent shade	23.30	24.78	25.18	25.57	26.57	26.41^{b}	30.23^{ab}	46.09^{a}	62.40^{b}	78.50^{ab}	55.2
T2	25 per cent shade	22.75	23.58	24.85	25.30	26.07	26.44	27.17^{c}	40.95^{b}	54.64^{c}	66.19^{c}	43.44
T3	50 per cent shade	24.44	25.36	26.17	27.98	28.34	28.78^{ab}	31.87^{a}	47.42^{a}	66.92^{a}	84.49^{a}	60.05
T4	75 per cent shade	23.77	26.47	26.61	28.35	28.68	29.78^{a}	29.09^{bc}	45.17^{ab}	59.87^{b}	72.67^{bc}	48.90
F test		NS	NS	NS	NS	NS	*	*	**	**	*	
SEm±		1.23	1.24	1.34	1.55	1.48	0.94	0.95	1.25	2.19	3.87	

NS – Not significant ** Significant at 1 per cent level * Significant at 5 per cent level
Figures with similar letters as superscript do not differ significantly

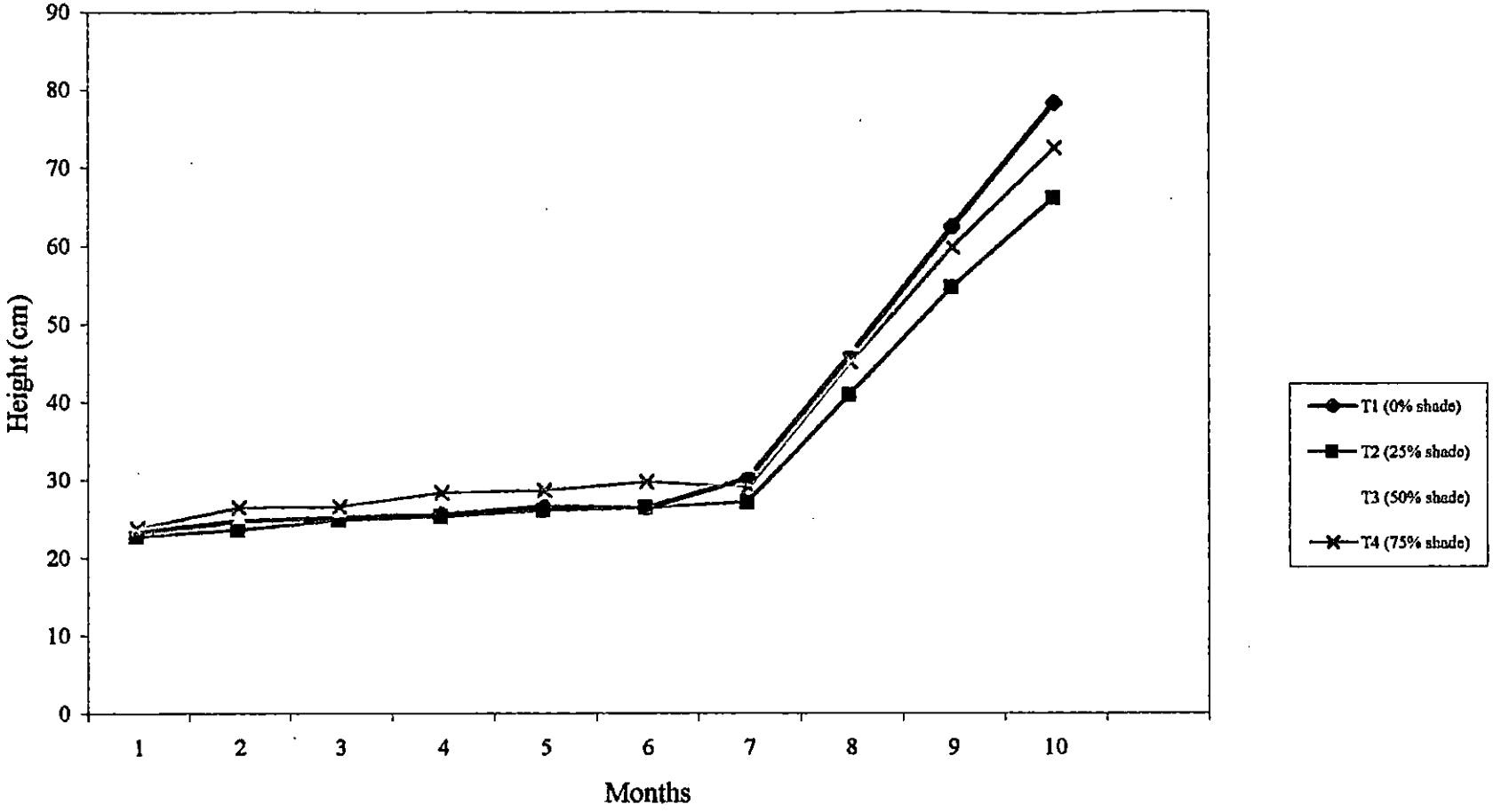

Fig.1. Effect of shade on height of seedlings of *Terminalia tomentosa*

(50% shade) while the minimum (43.44%) was recorded by T_2 (25% shade). The treatment T_1 and T2 recorded a height increment of 55.20 cm. and 43.44 cm. respectively. The results of DMRT analysis revealed that seedlings grown under 50 per cent shade were superior to all other treatments. The poor performance with regard to this parameter was recorded by seedlings grown under 25 per cent shade. There was not much difference in height growth of seedlings grown under 50 per cent and 0 per cent shade during the second half of the study. The effect of shade on height at the end of the study is shown in Plate 4.

In case of seedling height, in *Terminalia bellirica* significant effect was noticed from the sixth month to eighth month only (Table 2). The height growth of *T.bellirica* as influenced by shade is depicted in Figure 2 also. At the end of the study, maximum height of 43.44cm was recorded in treatment T_3 (50% shade) followed by T_4 (75% shade), T_1 (0% shade) and T_2 (25% shade) where height growth was respectively 42.78 cm, 41.76cm, and 37.38cm. Height growth was on par in seedlings grown in treatments T_2 and T_3 during the first two months of the study. Similarly, the height growth was on par in all the treatments during first, second, third and fifth month of observations. During the sixth to eight month height growth in treatments, T_1 (0% shade) and T_2 (25%shade) were on par and after which the growth in T_1 increased rapidly. Similarly, the heights of plants as influenced by treatment T_3 and T_4 were not significantly different during most of the periods of observation. At the end of the study, maximum total increment in height (26.99 cm) was recorded by T_3 (50% shade) and minimum total increment (20.84 cm.) was shown by the treatment T_2 (25% shade). The total increment recorded by treatments T_1 and T_4 at the end of the study

Table 2. Effect of shade on height (cm) of seedlings of *Terminalia bellirica* at monthly intervals

Treatment number	Treatment details	Age (months after planting)										Total increment
		1	2	3	4	5	6	7	8	9	10	
T_1	0 per cent shade	14.91	15.10	15.30	15.51	15.74	16.80^{b}	17.36^{b}	27.79^{b}	37.99	41.76	26.85
T_2	25 per cent shade	16.54	16.72	16.55	16.37	16.31	16.18^{b}	17.20^{b}	27.84^{b}	32.40	37.38	20.84
T_3	50 per cent shade	16.45	16.66	17.46	18.24	18.88	19.49^{a}	21.22^{a}	30.70^{a}	36.68	43.44	26.99
T_4	75 per cent shade	15.65	15.92	16.05	16.34	16.43	17.05^{b}	18.12^{b}	29.73^{ab}	36.42	42.78	27.13
F test		NS	NS	NS	NS	NS	*	**	*	NS	NS	
SEm±		0.80	0.79	0.78	0.46	1.01	0.94	0.41	0.90	1.82	3.56	

NS – Not significant ** Significant at 1 per cent level * Significant at 5 per cent level
Figures with similar letters as superscript do not differ significantly

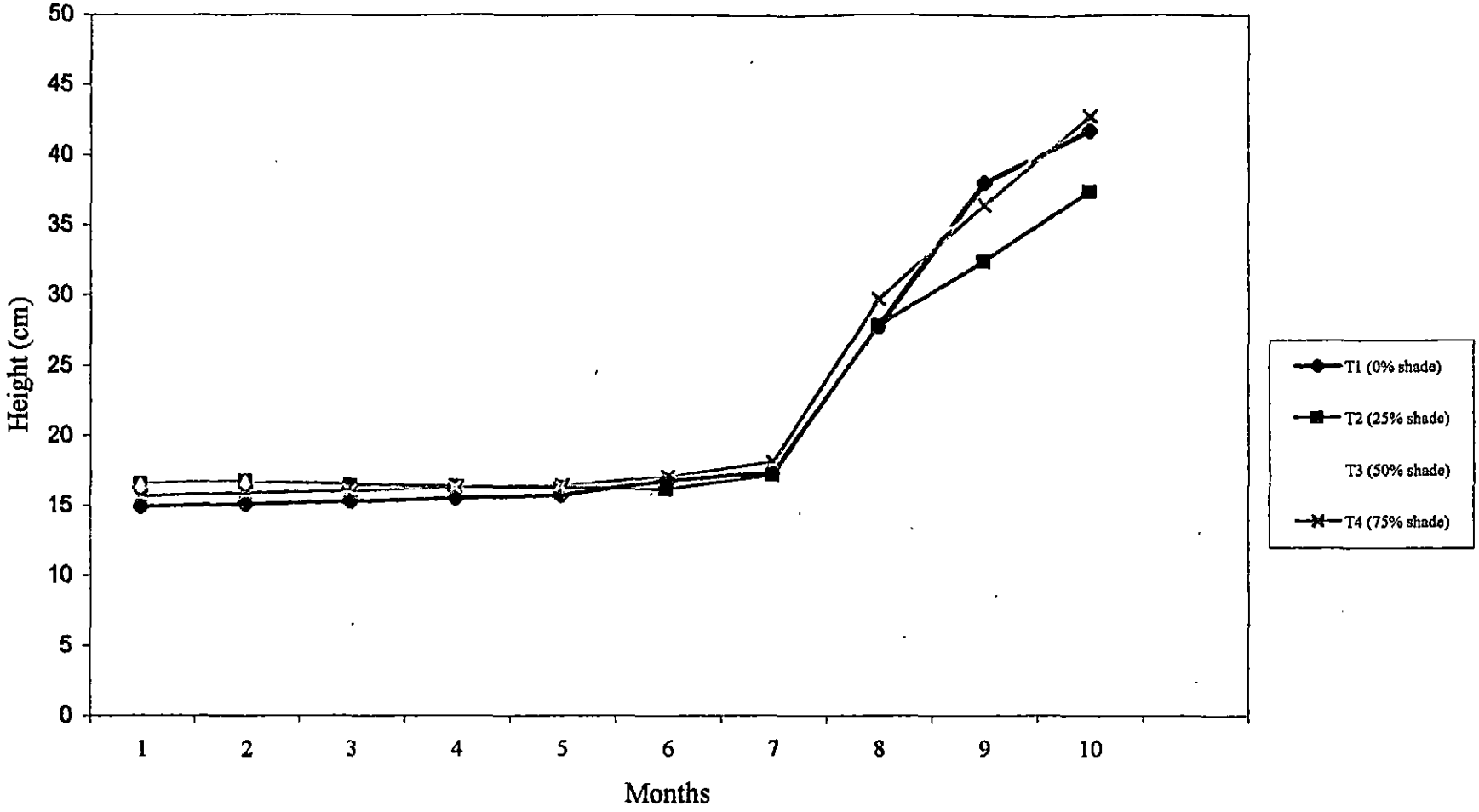

Fig.2. Effect of shade on height of seedlings of *Terminaia bellirica*

were respectively 26.85 cm and 27.13 cm. Regarding the efficiency of various treatments, DMRT analysis revealed the superiority of 50 per cent shade in relation to height growth in *T.bellerica.* The effect of shade on growth of seedlings at the end of the study is shown in Plate 5.

The observations on the effect of shade on height of seedlings of *T. arjuna* are tabulated in Table 3 and Figure 3. It is evident from the data, that there is no significant effect of shade on the height growth of *T. arjuna* seedlings in the nursery during most of the periods of observation. There was significant difference in height growth due to shade during the fifth, sixth and seventh months only. However, at the end of the tenth month, the treatment T_4 (75% shade) recorded relatively more height of 85.65 cm followed by T_2 (25% shade – 81.18 cm), T_3 (50% shade – 77.77 cm) and T_1 (0% shade- 75.32 cm). Almost a similar trend was noticed during entire course of the study. The data furnished in Table 3 also indicates that the total height increment ranged from 50.09 cm to 60.35 cm. The treatment T_4 (75% shade) topped the list followed by treatment T_2 (25% shade), T_3 (50% shade) and T_1 (0% shade). The superiority of seedlings grown under 75 per cent shade was clearly evident from the DMRT analysis. The seedlings grown under full sunlight performed least with regard to height growth in *T. arjuna.*

The effect of shade levels on growth of seedlings of *T. arjuna* is also depicted in Plate 6.

4.1.2 Collar girth

The collar girth of seedlings of *Terminalia tomentosa* showed significant difference as a result of shade during the second, third, seventh, eighth and ninth

Plate 4. Effect of varying levels of shade on growth of seedlings of *Terminalia tomentosa* at the end of the study

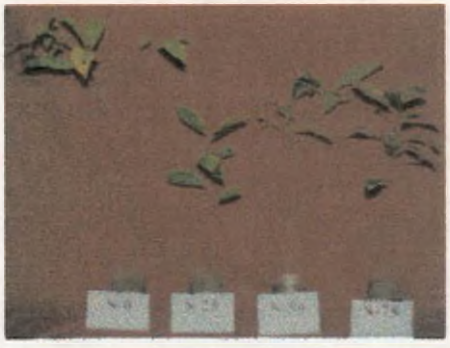

Plate 5. Effect of varying levels of shade on growth of seedlings of *Terminalia bellirica* at the end of the study

Plate 6. Effect of varying levels of shade on growth of seedlings of *Terminalia arjuna* at the end of the study

Table 3. Effect of shade on height (cm) of seedlings of *Terminalia arjuna* at monthly intervals

Treatment number	Treatment details	Age (months after planting)										Total increment
		1	2	3	4	5	6	7	8	9	10	
T_1	0 per cent shade	25.23	26.89	27.98	28.93	28.66^{b}	29.12^{d}	32.33^{c}	45.77	58.50	75.32	50.09
T_2	25 per cent shade	25.28	27.03	29.07	30.97	31.71^{ab}	31.85^{c}	34.30^{c}	47.98	65.44	81.18	55.90
T_3	50 per cent shade	26.12	28.25	30.22	31.43	32.82^{a}	35.67^{b}	41.73^{b}	52.68	63.46	77.77	51.65
T_4	75 per cent shade	25.30	25.89	26.65	28.98	30.58^{ab}	48.87^{a}	49.62^{a}	58.84	70.50	85.65	60.35
F test		NS	NS	NS	NS	**	**	**	NS	NS	NS	
SEm±		0.38	1.16	1.48	1.60	0.47	0.48	0.82	4.14	5.31	4.71	

NS – Not significant ** Significant at 1 per cent level
Figures with similar letters as superscript do not differ significantly

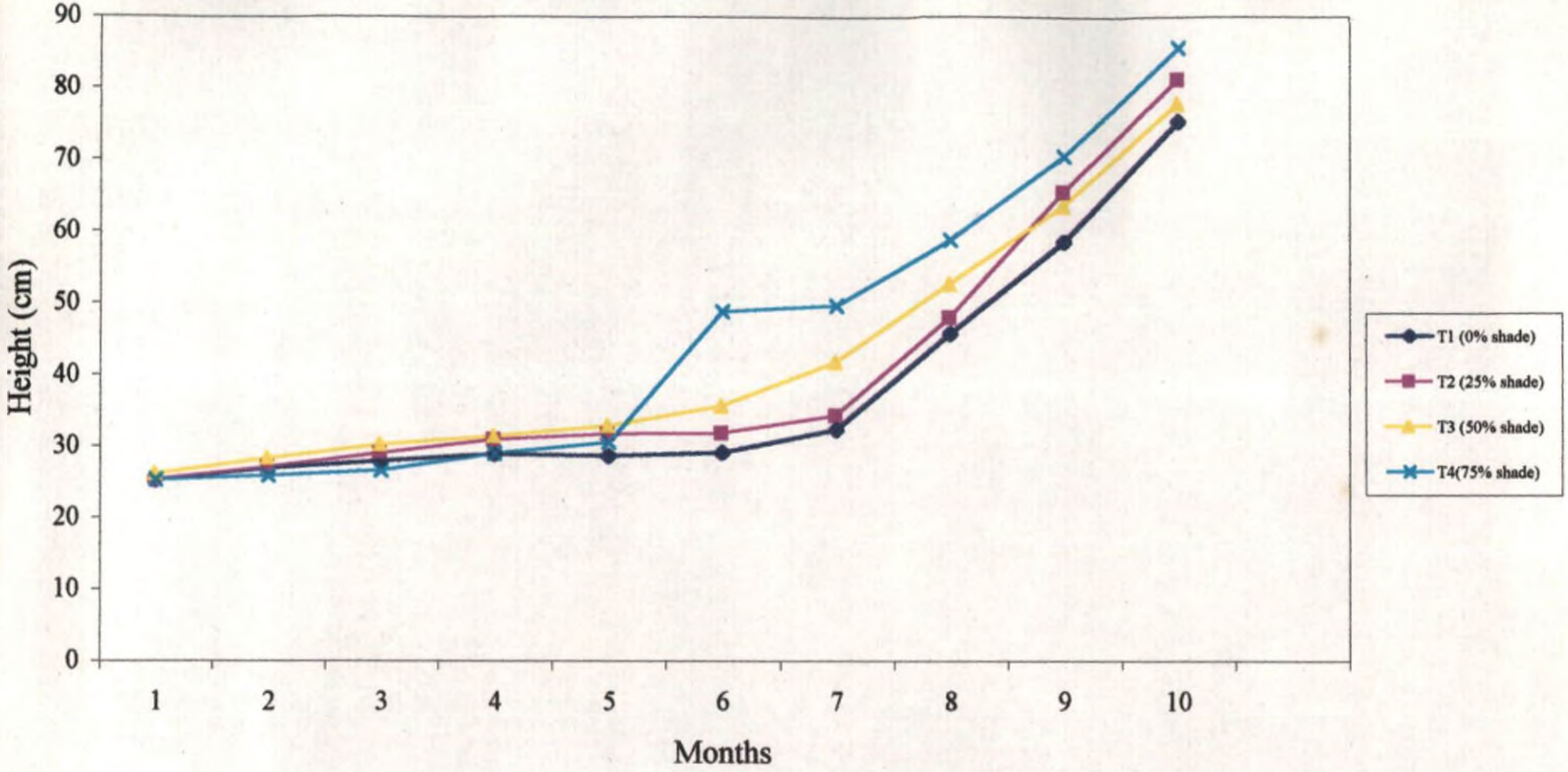

Fig.3. Effect of shade on height of seedlings of *Terminalia arjuna*

months of the study (Table 4). Figure 4 shows the effect of shade on collar girth on seedlings of *T. tomentosa*. The maximum collar girth at the end of the study was recorded by treatment T_3 (50% shade) where it was 7.46 cm followed by T_1 (0% shade) where it was 7.31 cm. However, difference between the two treatments was not significant. The treatment T_4 (75% shade) and T_2 (25% shade) recorded a girth of 7.27 cm and 6.32 cm respectively at the end of the study during the tenth month. It could also be seen from the data that the treatment T_2 (25% shade) is inferior with regard to girth of seedlings during the entire periods of observation. The total collar girth increment was maximum in treatment T_3 (50% shade – 5.37cm) followed by T_1 (0% shade – 5.19cm) and T_4 (75% shade – 5.18 cm) .The lowest girth increment of 4.35 cm was recorded by seedlings grown under the treatment T_2 (25% shade). The DMRT analysis revealed the superiority of treatment T_1 (0% shade) particulerly during the initial stages of the study and T_3 (50% shade) towards the end of the study.

The effect of shade on collar girth of *T. bellirica* is evident from the data furnished in Table 5 and Figure 5. It could be seen from the table that the collar girth up to fourth month and during seventh and tenth months was not significantly affected due to shade treatment. However, during the other months, i.e. fifth, sixth, eighth and ninth month shade significantly affected the collar girth of seedlings. The treatment T_3 (50% shade) recorded maximum collar girth of 6.95 cm followed by treatment T_4 (75% shade) where it was 6.62 cm during the tenth month. With regard to girth increment, treatment T3 (50% shade) produced maximum (3.88 cm) while the minimum of 3.44 cm was noticed in treatment T_1 (0% shade). The girth increment in seedlings grown under 25 and 75 per cent shades at the end of the study was

Table 4. Effect of shade on collar girth (cm) of seedlings of *Terminalia tomentosa* at monthly intervals

Treatment number	Treatment details	Age (months after planting)										Total increment
		1	2	3	4	5	6	7	8	9	10	
T_1	0 per cent shade	2.12	2.86^{a}	3.24^{a}	3.56	3.92	3.98	4.04^{b}	4.91^{b}	5.93^{b}	7.31	5.19
T_2	25 per cent shade	1.97	2.32^{c}	2.81^{b}	3.34	3.98	4.03	4.03^{b}	4.83^{b}	5.34^{c}	6.32	4.35
T_3	50 per cent shade	2.09	2.63^{b}	2.99^{ab}	3.38	4.07	4.25	4.23^{ab}	4.96^{b}	6.08^{a}	7.46	5.37
T_4	75 per cent shade	2.09	2.58^{b}	3.08^{ab}	3.57	4.32	4.47	4.59^{a}	5.48^{a}	5.77^{b}	7.27	5.18
F test		NS	**	*	NS	NS	NS	*	*	**	NS	
SEm±		0.06	0.05	0.10	0.19	0.22	0.24	0.13	0.15	0.09	0.38	

NS – Not significant ** Significant at 1 per cent level * Significant at 5 per cent level
Figures with similar letters as superscript do not differ significantly

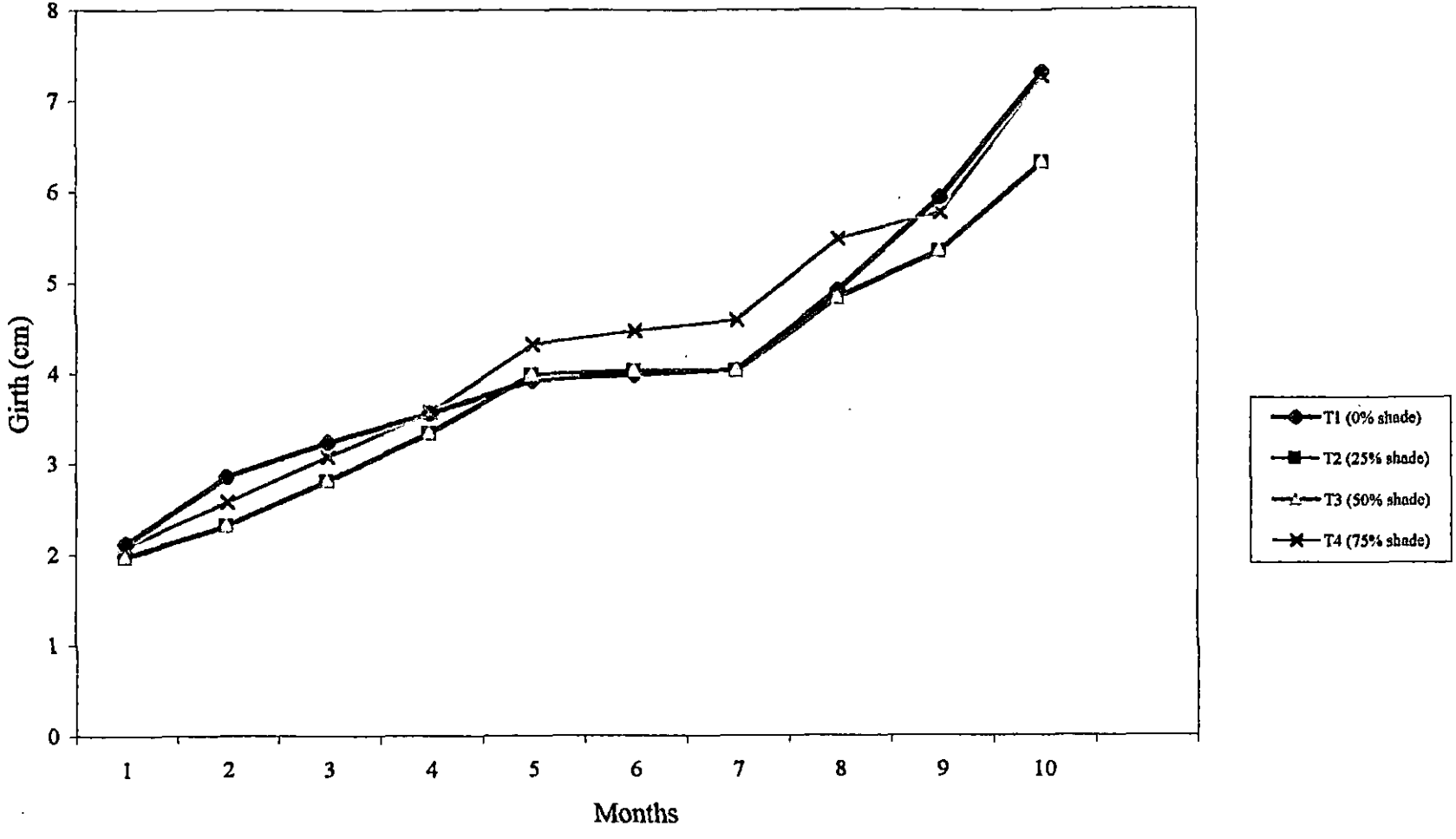

Fig.4. Effect of shade on collar girth of seedlings of *Terminalia tomentosa*

Table 5. Effect of shade on collar girth (cm) of seedlings of *Terminalia bellirica* at monthly intervals

Treat-ment number	Treat-ment details	Age (months after planting)										Total increment
		1	2	3	4	5	6	7	8	9	10	
T_1	0 per cent shade	2.97	3.10	3.23	4.16	4.42^{b}	4.76^{ab}	4.75	5.29^{b}	5.75^{b}	6.41	3.44
T_2	25 per cent shade	2.66	3.08	3.62	3.80	4.05^{b}	4.21^{b}	4.58	5.08^{b}	5.53^{b}	6.50	3.84
T_3	50 per cent shade	3.07	3.28	3.54	4.30	4.88^{a}	5.07^{a}	5.23	6.00^{a}	6.54^{a}	6.95	3.88
T_4	75 per cent shade	2.91	3.22	3.53	3.57	4.08^{b}	4.47^{b}	5.00	5.93^{a}	5.55^{b}	6.62	3.71
F test		NS	NS	NS	NS	**	**	NS	**	**	NS	
SEm±		0.15	0.12	0.20	0.41	0.12	0.14	0.26	0.12	0.18	0.26	

NS – Not significant ** Significant at 1 per cent level
Figures with similar letters as superscript do not differ significantly

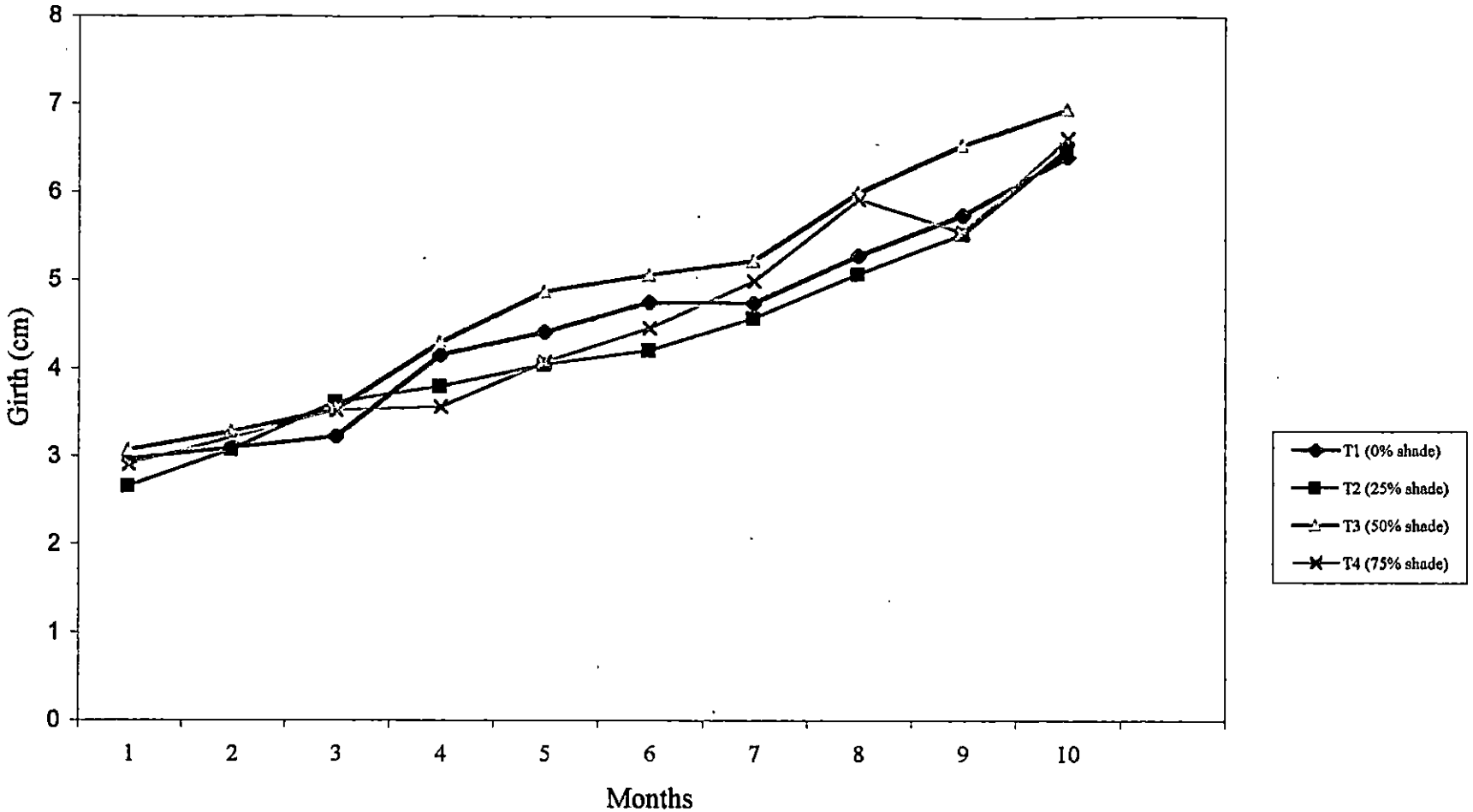

Fig.5. Effect of shade on collar girth of seedllings of *Terminaia bellirica*

respectively 3.84 cm and 3.71 cm. The superiority of treatment T_3 (50% shade) during the entire course of observation was revealed by the DMRT analysis.

The observations on the effect of shade on collar girth of *T.arjuna* are tabulated and shown in Table 6. It is evident from the table that the collar girth is significantly affected by shade except during the first, fourth and the last months of the study. Figure 6 shows the effect of shade on collar girth on seedlings of *T. arjuna.* At the end of the study, i.e., during the tenth month, maximum collar girth was shown by the treatment T_4 (75% shade), followed by T_2 (25% shade), T_3 (50% shade) and T_1 (0% shade). However, the differences between these treatments were not statistically significant. It is also evident from the data that there was significant difference between the collar girths of seedlings grown under different shade levels in the second half of the study. The maximum increment in collar girth of *T. arjuna* was recorded by treatment T_4 (6.27 cm) while the minimum by T_1 (5.28 cm). The girth increment in treatment T_3 and T_2 were respectively 5.35 and 6.02 cm. Like other two species, here also DMRT analysis in general, revealed the superiority of T_3 (50% shade). Generally, all the shade treatments were found better when compared to open sunlight with regard to girth increment.

4.1.3 Leaf production

In *Terminalia tomentosa,* there exists significant difference between the treatments, with regard to number of leaves (Table 7). At the end of the study period, maximum number of leaves (50.56) was shown by treatment T_4 (75% shade) followed by T_1 (0% shade) and T_3 (50% shade). The lowest leaf number (28.80) was recorded by seedlings grown under 25 per cent shade. The number of leaves produced by

Table 6. Effect of shade on collar girth (cm) of seedlings of *Terminalia arjuna* at monthly intervals

Treatment number	Treatment details	Age (months after planting)										Total increment
		1	2	3	4	5	6	7	8	9	10	
T_1	0 per cent shade	2.27	3.13^{b}	3.78^{b}	4.27	4.39+B	4.54^{b}	4.69^{b}	5.65^{b}	6.61^{c}	7.55	5.28
T_2	25 per cent shade	2.33	3.14^{b}	4.16^{a}	5.01	6.02^{a}	6.26^{a}	6.39^{a}	7.22^{a}	8.12^{a}	8.35	6.02
T_3	50 per cent shade	2.49	3.55^{a}	4.23^{a}	4.95	5.58^{a}	6.02^{a}	6.16^{a}	6.72^{a}	7.25^{bc}	7.84	5.35
T_4	75 per cent shade	2.32	3.00^{b}	3.73^{b}	4.61	5.68^{a}	6.23^{a}	6.34^{a}	6.87^{a}	7.59^{b}	8.59	6.27
F test		NS	*	*	NS	**	**	**	**	*	NS	
SEm±		0.11	0.14	0.15	0.35	0.29	0.29	0.21	0.23	0.29	0.43	

NS – Not significant ** Significant at 1 per cent level * Significant at 5 per cent level
Figures with similar letters as superscript do not differ significantly

Table 7. Effect of shade on leaf production (number) of seedlings of *Terminalia tomentosa* at monthly intervals

Treatment number	Treatment details	Age (months after planting)										Total increment
		1	2	3	4	5	6	7	8	9	10	
T_1	0 per cent shade	11.74	12.84^{a}	13.69^{a}	14.37^{a}	9.25^{a}	8.53^{a}	16.87^{a}	24.40	32.07^{ab}	37.32^{ab}	25.58
T_2	25 per cent shade	11.30	10.93^{b}	11.86^{b}	11.35^{b}	6.28^{b}	6.05^{b}	10.77^{b}	16.67	23.00^{b}	28.80^{b}	17.50
T_3	50 per cent shade	11.15	11.50^{b}	11.92^{b}	12.20^{b}	8.92^{a}	8.57^{a}	3.15^{c}	17.53	28.83^{ab}	35.75^{ab}	24.60
T_4	75 per cent shade	11.80	12.67^{a}	13.20^{ab}	14.21^{a}	9.67^{a}	9.71^{a}	9.87^{b}	24.53	37.63^{a}	50.56^{a}	38.76
F test		NS	*	*	*	*	*	**	NS	*	*	
SEm±		0.37	0.47	0.55	0.74	0.97	0.87	0.96	2.88	3.90	5.85	

NS – Not significant ** Significant at 1 per cent level * Significant at 5 per cent level
Figures with similar letters as superscript do not differ significantly

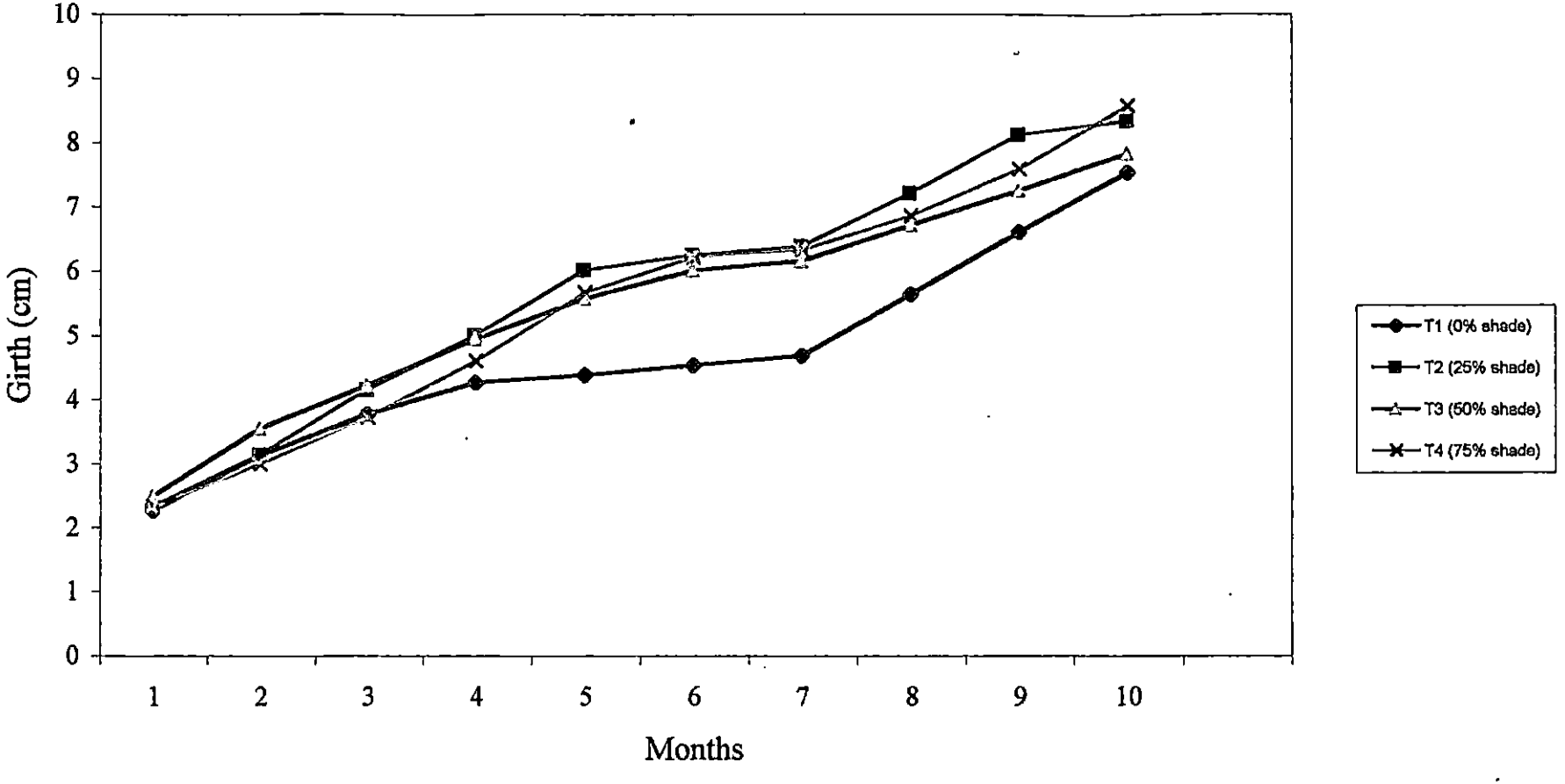

Fig.6. Effect of shade on collar girth of seedlings of *Terminalia arjuna*

treatments T_1 (0% shade) and T_3 (50% shade) were almost on par throughout the period of study. Similarly, the number of leaves produced by seedlings during the first and eighth month was not significantly different. With regard to total increment, treatment T_4 (75% shade) recorded the maximum (38.76) followed by T_1 (0% shade), T_3 (50% shade) and T_2 (25% shade) where the increments in the number of leaves was respectively 24.60, 25.58 and 17.50 at the end of the study.

In case of *T. bellirica* also, treatments differed significantly with regard to leaf production (Table 8). It could be seen from the table that there was no significant difference between the treatments with regard to shade from first to fourth months and also during the tenth month of the study. It could be seen from the data that in treatment T_4 (75% shade), leaf number increased from 6.83 during the first month to 17.98 in the tenth moth, while the respective increase in treatment T_1 (0% shade), T_2 (25% shade), and T_3 (50% shade) were from 5.96 to 16.29, 6.15 to 12.61, 5.90 to 14.89 respectively from beginning to the end of the study. In general, treatment T_2 (25% shade) was found to be inferior with regard to this parameter.

The observations on the effect of shade on the leaf production of *T. arjuna* is tabulated in Table 9. The treatments did not produce any significant effect on leaf production till the fourth month. However from the fifth to tenth month, the effect was statistically significant. With regard to leaf production, the superiority of treatment T_4 (75% shade) from fifth to tenth month is clearly evident from the data. At the end of the tenth month, number of leaves produced by seedlings grown under 75 per cent shade was 107.4. while the lowest number of 52.34 was noticed by seedlings grown under full sunlight (0 % shade). The seedlings grown under full sunlight were

Table 8. Effect of shade on leaf production (number) of seedlings of *Terminalia bellirica* at monthly intervals

Treatment number	Treatment details	Age (months after planting)										Total increment
		1	2	3	4	5	6	7	8	9	10	
T_1	0 per cent shade	5.96	6.81	6.50	5.30	3.44^{b}	3.81^{b}	6.25^{ab}	9.32^{b}	12.79^{ab}	16.29	10.33
T_2	25 per cent shade	6.15	6.95	6.84	6.04	2.17^{c}	1.04^{c}	4.41^{b}	7.14^{c}	9.81^{b}	12.61	6.46
T_3	50 per cent shade	5.90	6.60	5.98	4.84	4.90^{a}	2.04^{c}	4.76^{b}	8.06^{bc}	11.35^{b}	14.89	8.99
T_4	75 per cent shade	6.83	7.66	7.46	6.48	5.59^{a}	5.72^{a}	8.22^{a}	11.40^{a}	14.73^{a}	17.98	11.15
F test		NS	NS	NS	NS	**	**	**	**	**	NS	
SEm±		0.46	0.55	0.60	1.18	0.28	0.36	0.76	0.43	0.84	1.54	

NS – Not significant ** Significant at 1 per cent level
Figures with similar letters as superscript do not differ significantly

Table 9. Effect of shade on leaf production (number) of seedlings of *Terminalia arjuna* at monthly intervals

Treatment number	Treatment details	Age (months after planting)										Total increment
		1	2	3	4	5	6	7	8	9	10	
T_1	0 per cent shade	16.28	18.98	20.96	20.49	14.54^{b}	19.12^{b}	23.20^{b}	28.52^{b}	33.03^{b}	52.34^{b}	36.06
T_2	25 per cent shade	15.88	18.81	21.70	25.17	21.01^{b}	21.63^{b}	40.45^{a}	50.76^{a}	65.41^{a}	79.92^{ab}	64.04
T_3	50 per cent shade	17.41	20.58	24.22	27.58	23.06^{ab}	23.86^{ab}	32.60^{ab}	59.91^{a}	80.43^{a}	97.80^{a}	80.39
T_4	75 per cent shade	16.80	19.05	25.56	30.66	32.20^{a}	34.69^{a}	43.66^{a}	61.81^{a}	88.76^{a}	107.44^{a}	90.60
F test		NS	NS	NS	NS	**	**	**	**	**	**	
SEm±		0.98	139	2.73	4.28	2.82	3.20	3.23	3.50	7.10	10.48	

NS – Not significant ** Significant at 1 per cent level
Figures with similar letters as superscript do not differ significantly

found to be inferior throughout the course of the investigation with regard to this parameter.

4.1.4 Leaf area

In *T. tomentosa*, there exist significant differences between treatments with regard to leaf area (Table 10). The leaf area was affected by shade except during first, eighth and tenth month of the study. At the end of the study, the maximum leaf area of 101.04 cm^2 was recorded by treatment T_4 (75% shade) followed by T_3 and T_1. Plants grown under 25 per cent shade showed the minimum leaf area (68.83 cm^2). The superiority of treatment T_1 in the second, third and fourth month is also evident from the data. With regard to this parameter, there was no significant difference between 75 per cent and 50 per cent shade levels during the second half of the study.

Data tabulated in Table 11 depict the effect of shade levels on leaf area of *T. bellirica*. It is clear from the data that there was significant influence of shade on the leaf area during fifth to ninth month of the study. The maximum leaf area at the end of the study (64.36 cm^2) was recorded by T_4 (75% shade) followed by T_1 (0% shade) and T_3 (50% shade) while the minimum leaf area (45.16 cm^2) at the end of the study was recorded by T_2 (25% shade). Seedlings grown under T_4 (75% shade) were showing higher leaf area during entire period of observation.

A perusal of data furnished in Table 12 indicates that in *T. arjuna*, the shade levels made significant difference in leaf area between the treatments only during the second half of the study. The maximum leaf area exhibited by T_4 (75% shade) was 84.78 cm^2 followed by T_3 (50% shade) and T_2 (25% shade). The minimum leaf area of 26.77 cm^2 was shown by T_1 (0% shade). The superiority of treatment T_4

Table 10. Effect of shade on leaf area (cm^2) of seedlings of *Terminalia tomentosa* at monthly intervals

Treat-ment number	Treat-ment details	Age (months after planting)									
		1	2	3	4	5	6	7	8	9	10
T1	0 per cent shade	28.07	30.68^{a}	32.72^{a}	34.34^{a}	22.11^{a}	20.38^{a}	40.31^{a}	58.32	76.66^{ab}	89.19
T2	25 per cent shade	27.00	26.12^{b}	28.35^{b}	27.12^{b}	15.02^{b}	14.47^{b}	25.75^{b}	39.84	54.96^{b}	68.83
T3	50 per cent shade	26.66	27.49^{b}	28.48^{b}	29.16^{b}	21.31^{a}	20.49^{a}	21.53^{b}	41.90	68.90^{ab}	89.42
T4	75 per cent shade	28.20	30.28^{a}	31.56^{ab}	33.95^{a}	23.10^{a}	23.21^{a}	23.58^{b}	58.62	89.93^{a}	101.04
F test		NS	*	*	*	*	*	*	NS	*	NS
SEm±		0.88	1.12	1.32	1.77	2.32	2.08	2.30	6.88	9.32	14.94

NS – Not significant * Significant at 5 per cent level
Figures with similar letters as superscript do not differ significantly

Table 11. Effect of shade on leaf area (cm^2) of seedlings of *Terminalia bellirica* at monthly intervals

Treatment number	Treatment details	Age (months after planting)									
		1	2	3	4	5	6	7	8	9	10
T_1	0 per cent shade	21.34	24.37	23.28	18.97	12.32^{b}	13.64^{b}	22.39AB	33.37^{b}	45.80^{ab}	58.33
T_2	25 per cent shade	22.02	24.89	24.49	21.62	7.76^{c}	3.71^{c}	15.78^{b}	25.57^{c}	35.13^{b}	45.16
T_3	50 per cent shade	21.12	23.63	21.40	17.32	17.55^{a}	7.32^{c}	17.04^{b}	28.85^{bc}	40.62^{b}	53.32
T_4	75 per cent shade	24.44	27.41	26.69	23.21	20.02^{a}	20.48^{a}	29.42^{a}	40.82^{a}	52.75^{a}	64.36
F test		NS	NS	NS	NS	**	**	**	**	**	NS
SEm±		1.65	1.98	2.16	4.24	1.01	1.27	2.73	1.53	3.02	5.51

NS – Not significant ** Significant at 1 per cent level
Figures with similar letters as superscript do not differ significantly

Table12. Effect of shade on leaf area (cm^2) of seedlings of *Terminalia arjuna* at monthly intervals

Treatment number	Treatment details	Age (months after planting)									
		1	2	3	4	5	6	7	8	9	10
T_1	0 per cent shade	11.89	13.85	15.30	14.96	10.61^{b}	13.96^{b}	16.93^{b}	20.82^{b}	24.11^{b}	26.77^{b}
T_2	25 per cent shade	11.59	13.73	15.84	18.37	15.34^{b}	15.79^{b}	29.53^{a}	37.06^{a}	47.75^{a}	58.34^{ab}
T_3	50 per cent shade	12.71	15.03	17.68	20.13	16.83^{ab}	17.42^{ab}	23.80^{ab}	43.74^{ab}	58.71^{a}	75.77^{a}
T_4	75 per cent shade	12.27	13.91	18.66	22.38	23.51^{a}	25.32^{a}	31.87^{a}	45.12^{a}	64.79^{a}	84.78^{a}
F test						**	**	**	**	**	**
SEm±		0.71	1.01	1.99	3.13	2.06	2.34	2.36	2.55	5.18	8.57

NS – Not significant ** Significant at 1 per cent level
Figures with similar letters as superscript do not differ significantly

was clear from the third month till the end of the study. It could also be seen from the table that, leaf area of treatment T_4 (84.78 cm^2) was more than thrice the leaf area of T_1 (26.77 cm^2) at the end of the study.

4.2 Effect of shade on root growth parameters

The observations on various root growth characteristics viz. length and spread of the three species of Terminalia as influenced by various shade levels are furnished in Table 13 to 18.

4.2.1 Root length

In *Terminalia tomentosa*, the treatment manifested significant influence on length of roots during third to sixth month of the study and also in the eighth month (Table 13). However, root length was not significantly influenced during the other periods of observation. The root length was found to be maximum (57.97 cm) when grown under 0 per cent shade and this was followed by treatments T_2 (57.80 cm) and T_3 (57.27 cm). The minimum root length of 56.63 cm was recorded by T_4 (75% shade) at the end of the study. However, the differences between the treatments were not significant.

In *T. bellirica,* the influence of shade on root length was significant from second to fifth month and at the end of the study i.e. during the ninth and tenth month (Table 14). The observation recorded during the tenth month revealed the maximum root length (58.48 cm) for treatment T_1 (0% shade) followed by treatments T_2 (25% shade), T_3 (50% shade) and T_4 (75% shade). Generally in all the treatments, roots were growing at a higher rate initially, followed by a reduction towards the end of the study.

Table 13. Effect of shade on length (cm) of roots of *Terminalia tomentosa* seedlings at monthly intervals

Treat-ment number	Treat-ment details	Months									
		1	2	3	4	5	6	7	8	9	10
T1	0 per cent shade	12.33	16.50	25.53^{a}	33.20^{a}	34.43^{a}	38.62^{a}	39.87	47.83^{b}	50.90	57.97
T2	25 per cent shade	12.40	16.40	14.50^{c}	22.43^{b}	29.63^{b}	34.57^{b}	36.23	47.60^{b}	52.27	57.80
T3	50 per cent shade	13.10	16.47	18.60^{b}	26.53^{b}	28.10^{b}	30.33^{c}	38.50	48.20^{ab}	52.47	57.27
T4	75 per cent shade	12.50	16.20	20.27^{b}	32.63^{a}	32.23^{ab}	35.53^{ab}	38.00	49.08^{a}	53.37	56.63
F test		NS	NS	**	**	**	**	NS	**	NS	NS
CD (0.05)				1.96	2.82	2.70	2.07		0.61		
SEm±		0.47	0.12	0.80	1.15	1.10	0.84	0.99	0.25	1.64	0.80

NS – Not significant ** Significant at 1 per cent level * Significant at 5 per cent level

Table 14. Effect of shade on length (cm) of roots of *Terminalia bellirica* seedlings at monthly intervals

Treatment number	Treatment details	Age (months after planting)									
		1	2	3	4	5	6	7	8	9	10
T_1	0 per cent shade	15.10	23.40^a	28.54^a	30.04^a	32.17^a	29.30	48.06	52.35	56.20^a	58.48^a
T_2	25 per cent shade	14.37	11.23^d	13.97^c	20.60^b	32.97^a	32.83	50.05	49.60	51.21^c	54.79^b
T_3	50 per cent shade	15.50	18.37^c	25.87^{ab}	30.08^a	30.50^a	32.20	50.03	50.28	53.23^b	52.41^c
T_4	75 per cent shade	14.80	21.03^b	23.70^b	29.85^a	29.10^a	33.20	50.65	50.47	51.46^c	52.36^c
F test		NS	**	**	**	**	NS	NS	NS	*	**
SEm±		0.90	0.47	1.04	1.24	1.05	1.44	1.44	1.79	1.41	0.42

NS – Not significant ** Significant at 1 per cent level * Significant at 5 per cent level
Figures with similar letters as superscript do not differ significantly

In *T. arjuna*, there was significant influence of different levels of shade on the tap root length as is evident from the data furnished in Table 15. In this species, the treatments did not exert any significant influence on the root length during the first two months of the study. At the end of the study, maximum root length (70.64 cm) was recorded for treatment T_4 (75% shade) followed by T_2 (25% shade), T_3 (50% shade) and T_1 (0% shade).

4.2.2 Root spread

Unlike toot length, the spread of roots in *T. tomentosa* did not show much significant difference between the treatments (Table 16). Treatments differ significantly with regard to root spread from second to fifth month after planting. From sixth to tenth month, there was no significant difference between the treatments with regard to this parameter.

In *T. bellirica* also, during most of the periods of observation, the treatments were not significantly different (Table 17). The highest root spread at the end of the study was 17.38 cm, for seedlings grown in full sunlight. This was followed by treatment T_4 (75% shade), T_3 (50% shade) and T_2 (25% shade).

The root spread of *T. arjuna* as seen from Table 18, varied significantly with respect to shade levels except during the initial months and in the sixth month of the study. The maximum root spread of 17.60 cm was recorded by seedlings grown under 75 per cent shade, followed by T_2 (25% shade) and T_3 (50% shade). The lowest root spread of 16.03 cm was shown by treatment T_1 (0% shade) at the end of the study.

Table15. Effect of shade on length (cm) of roots of *Terminalia arjuna* seedlings at monthly intervals

Treatment number	Treatment details	Age (months after planting)									
		1	2	3	4	5	6	7	8	9	10
T_1	0 per cent shade	21.80	30.73	52.53^{a}	61.26^{a}	35.43^{c}	33.66^{b}	29.75^{d}	38.12^{c}	52.34^{c}	59.37^{b}
T_2	25 per cent shade	19.80	29.62	31.00^{b}	37.02^{c}	37.07^{c}	37.39^{b}	35.04^{c}	52.45^{b}	59.61^{b}	61.43^{b}
T_3	50 per cent shade	20.28	30.47	35.04^{b}	39.39^{bc}	47.76^{b}	46.26^{ab}	50.70^{a}	51.41^{b}	57.28^{b}	59.95^{b}
T_4	75 per cent shade	21.30	30.07	37.93^{b}	44.56^{b}	61.35^{a}	51.79^{a}	44.86^{b}	65.44^{a}	68.29^{a}	70.64^{a}
F test		NS	NS	*	**	**	**	**	**	**	**
SEm±		1.08	1.08	4.71	1.62	1.54	3.28	1.38	1.03	0.64	1.07

NS – Not significant ** Significant at 1 per cent level * Significant at 5 per cent level
Figures with similar letters as superscript do not differ significantly

Table 16. Effect of shade on spread (cm) of roots of *Terminalia tomentosa* seedlings at monthly intervals

Treatment number	Treatment details	Age (months after planting)									
		1	2	3	4	5	6	7	8	9	10
T1	0 per cent shade	5.30	9.70^{a}	10.60^{b}	16.53^{a}	19.00^{a}	17.67	18.43	18.62	20.45	21.00
T2	25 per cent shade	5.60	10.40^{a}	12.00^{a}	14.46^{b}	16.50^{ab}	16.00	18.00	18.49	20.20	20.53
T3	50 per cent shade	5.40	6.30^{b}	9.63^{c}	11.51^{c}	13.50^{b}	15.01	16.50	17.46	19.74	20.97
T4	75 per cent shade	5.63	4.10^{b}	8.93^{d}	10.62^{c}	13.60^{b}	15.30	16.90	16.96	19.73	20.73
F test		NS	**	**	**	**	NS	NS	NS	NS	NS
SEm±		0.14	0.87	0.17	0.41	0.82	0.94	0.63	0.53	0.89	1.03

NS – Not significant ** Significant at 1 per cent level
Figures with similar letters as superscript do not differ significantly

Table 17. Effect of shade on spread (cm) of roots of *Terminalia bellirica* seedlings at monthly intervals

Treatment number	Treatment details	Age (months after planting)									
		1	2	3	4	5	6	7	8	9	10
T_1	0 per cent shade	6.93	9.30	10.79[a]	12.95	12.50	12.33	13.95	16.44[a]	16.68[b]	17.38[a]
T_2	25 per cent shade	6.77	8.90	9.69[bc]	10.76	11.49	12.20	13.44	15.04[b]	16.06[c]	16.25[d]
T_3	50 per cent shade	6.97	9.03	9.43C	10.94	11.27	12.27	13.51	16.32[a]	16.62[b]	16.71[c]
T_4	75 per cent shade	6.93	9.10	10.53[ab]	11.67	1182	12.46	14.36	16.91[a]	17.06[a]	17.08[b]
F test		NS	NS	*	NS	NS	NS	NS	*	**	**
SEm±		0.38	0.27	0.37	0.72	0.37	0.09	0.49	0.43	0.07	0.07

NS – Not significant ** Significant at 1 per cent level * Significant at 5 per cent level
Figures with similar letters as superscript do not differ significantly

Table18. Effect of shade on spread (cm) of roots of *Terminalia arjuna* seedlings at monthly intervals

Treatment number	Treatment details	Age (months after planting)									
		1	2	3	4	5	6	7	8	9	10
T_1	0 per cent shade	7.30	9.82	9.15^{b}	15.90^{b}	16.00^{b}	14.46	11.41^{c}	11.76^{b}	15.61^{b}	16.03^{c}
T_2	25 per cent shade	7.16	9.73	12.21^{a}	18.63^{a}	21.30^{a}	16.58	10.36^{c}	14.93	15.46^{b}	17.32^{ab}
T_3	50 per cent shade	7.17	9.32	9.99^{b}	12.50^{c}	14.81^{b}	15.96	14.51^{b}	14.05^{a}	15.71^{b}	17.01^{ab}
T_4	75 per cent shade	7.21	8.63	12.57^{a}	15.61^{b}	16.50^{b}	16.55	16.23^{a}	15.08^{a}	16.09^{a}	17.60^{a}
F test		NS	NS	*	**	**	NS	**	**	**	*
SEm±		0.24	0.80	0.83	0.46	1.10	0.87	0.40	0.48	0.08	0.55

NS – Not significant ** Significant at 1 per cent level * Significant at 5 per cent level
Figures with similar letters as superscript do not differ significantly

4.3 Effect of shade on biomass production

4.3.1 Shoot fresh and dry weight

The data furnished in Table 19 indicate that in *T. tomentosa,* the biomass production is almost on par during most of the periods of observation. Significant differences between the treatments exist only in the second, third, fourth, ninth and tenth month of the study. At the end of the study, treatment T_3 (50% shade) recorded the maximum shoot fresh weight of 82.63 g followed by T_1 (0% shade) and T_4 (75% shade) while the minimum was recorded by T_2 (25% shade). Similar trend was noticed with regard to dry weight also. The dry weight at the end of the study was found to be maximum (36.23 g) for seedlings raised under 50 per cent shade while the lowest dry weight of 23.49 g was noticed by the seedlings raised under 25 per cent shade.

In the case of *T. bellirica,* the shoot fresh and dry weight differed significantly with respect to shade treatments during the fifth, sixth, and seventh month of observations (Table 20). Unlike in *T. tomentosa,* all the treatments were found to be on par in this species with regard to fresh and dry weights of shoots at the end of the study.

In *T. arjuna* there was significant difference with regard to shoot weight during the second half of the study i.e., after the fifth month (Table 21). The effect of shade on biomass production was not significant from first to fifth month. At the end of tenth month, maximum dry weight of 25.71 g was recorded by seedlings grown under 75 per cent shade, while minimum of 17.53 g was recorded by seedlings grown under full sunlight, without any shade.

Table 19. Effect of shade on weight (g) of shoots of *Terminalia tomentosa* seedlings at monthly intervals

Treatment number	Treatment details	Age (months after planting)																			
		1		2		3		4		5		6		7		8		9		10	
		FW	DW	FW	DW	FW	DW	FW	DW	FW	DW	FW	DW	FW	DW	FW	DW	FW	DW	FW	DW
T_1	0 per cent shade	5.84	2.00	6.44^{a}	2.29	10.17^{a}	3.25^{a}	13.38^{ab}	5.23^{ab}	17.27	5.55	3.01	1.02	2.86	2.11	25.67	12.04	65.99^{ab}	29.30^{ab}	69.85^{b}	30.98^{b}
T_2	25 per cent shade	6.36	2.23	5.56^{b}	1.98	6.52^{c}	2.30^{ab}	11.46^{c}	4.49^{b}	17.05	6.50	3.49	1.14	2.82	1.98	25.04	11.85	60.33^{b}	27.77^{b}	62.57^{b}	23.49^{c}
T_3	50 per cent shade	5.46	1.84	5.50^{b}	1.76	5.63^{c}	1.93^{b}	12.06^{bc}	2.49^{c}	16.42	5.10	3.07	1.08	2.43	1.48	28.21	13.29	71.22^{a}	31.65^{a}	82.63^{a}	36.23^{a}
T_4	75 per cent shade	5.19	1.97	5.25^{b}	2.56	8.06^{b}	3.21^{a}	14.11^{a}	5.94^{a}	17.58	6.36	3.00	1.04	2.95	1.22	29.79	13.22	65.09^{ab}	28.38^{b}	67.63^{b}	28.67^{b}
F test		NS	NS	*	NS	**	**	**	**	NS	NS	NS	NS	NS	NS	NS	NS	*	*	**	**
SEm±		0.49	0.24	0.24	0.56	0.30	.029	0.37	.022									2.68	1.04	3.19	.074

NS – Not significant ** Significant at 1 per cent level * Significant at 5 per cent level FW - Fresh weight DW – Dry weight
Figures with similar letters as superscript do not differ significantly

Table 20. Effect of shade on weight (g) of shoots of seedlings of *Terminalia bellirica* at monthly intervals

Treatment number	Treatment details	Age (months after planting)																			
		1		2		3		4		5		6		7		8		9		10	
		F W	DW	F W	DW	F W	DW	FW	DW	F W	DW	F W	DW	F W	DW	F W	DW	F W	DW	F W	DW
T_1	0 per cent shade	3.38	1.06	4.83	1.90	5.07	1.59	5.63	2.22	2.48^{b}	0.97^{b}	1.80^{b}	0.89^{c}	2.13^{c}	1.91^{a}	21.23	9.92	36.29	15.18	37.04	16.07
T_2	25 per cent shade	3.13	1.05	4.74	1.82	5.98	1.71	5.78	1.92	3.60^{b}	1.04^{b}	2.49^{b}	1.22b	3.98^{a}	2.20^{a}	21.77	7.86	35.25	14.18	37.97	16.08
T_3	50 per cent shade	3.43	1.06	4.34	1.45	5.51	1.82	5.74	2.34	8.55^{a}	1.01^{b}	4.39^{a}	1.63^{a}	4.35^{b}	1.54^{b}	22.14	8.34	35.15	14.19	37.23	14.87
T_4	75 per cent shade	3.39	1.08	4.63	1.39	5.13	1.33	5.65	2.61	8.54^{a}	2.96^{a}	4.95^{a}	1.76^{a}	6.60^{bc}	1.36^{b}	21.49	9.51	36.54	15.30	37.86	16.64
F test		NS	NS	NS	NS	NS	NS	NS	NS	**	**	**	**	**	**	NS	NS	NS	NS	NS	NS
SEm±		0.19	0.02	0.42	0.21	0.46	0.36	0.36	0.18	0.41	0.17	0.23	0.04	0.57	0.08	1.74	0.68	1.68	0.43	1.42	0.94

NS – Not significant ** Significant at 1 per cent level FW - Fresh weight DW – Dry weight
Figures with similar letters as superscript do not differ significantly

Table 21. Effect of shade on weight (g) of shoots of seedlings of *Terminalia arjuna* at monthly intervals

Treatment number	Treatment details	Age (months after planting)																			
		1		2		3		4		5		6		7		8		9		10	
		FW	DW	FW	DW	FW	DW	FW	DW	FW	DW	FW	DW	FW	DW	FW	DW	FW	DW	FW	
T_1	0 per cent shade	5.55	2.12	6.13	2.35	8.44	2.41	10.46	3.87	9.42	5.14	11.60^{a}	4.58^{c}	11.08^{c}	5.48^{b}	33.46^{d}	14.04^{c}	39.81^{c}	14.49^{b}	48.01^{c}	1
T_2	25 per cent shade	5.57	2.13	6.16	2.23	8.40	2.25	10.77	4.02	10.00	4.36	12.21^{a}	4.78^{bc}	13.30^{a}	5.39^{b}	38.46^{b}	15.25^{b}	54.34^{a}	22.33^{a}	57.37^{b}	2
T_3	50 per cent shade	5.61	2.26	6.10	2.35	8.77	2.87	10.89	3.99	11.14	5.74	14.37^{a}	6.44^{a}	13.32^{a}	7.39^{a}	36.09^{c}	15.16^{bc}	48.29^{b}	19.61^{a}	54.82^{b}	2
T_4	75 per cent shade	5.61	2.34	6.09	2.21	8.48	2.47	11.25	4.05	11.42	4.56	14.83^{a}	4.95^{b}	12.21^{b}	5.10^{b}	41.21^{a}	16.72^{a}	55.29^{a}	23.53^{a}	64.30^{a}	2
F test		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	**	**	**	**	**	**	**	**	
SEm±		0.47	0.30	0.37	0.33	0.94	0.42	0.58	0.45	0.84	0.45	3.07	0.07	0.08	0.34	0.47	0.31	0.93	0.77	0.91	(

NS – Not significant ** Significant at 1 per cent level * Significant at 5 per cent level FW - Fresh weight DW – Dry weight
Figures with similar letters as superscript do not differ significantly

4.3.2 Root fresh and dry weight

The data furnished in Table 22 indicate that in *T. tomentosa*, there was significant effect of shade on fresh weight of roots from fourth month till the end of the study. At the end of the study, maximum fresh and dry weights were shown by seedlings grown under T_3 (50% shade) followed by T_4 (75% shade) and T_1 (0% shade). The lowest fresh and dry weights of 23.37 g and 6.23 g respectively, were observed by seedlings grown under 25 per cent shade.

The root weight of *T. bellirica* (Table 23) was also found to be significantly affected by shade from sixth to ninth month. The maximum fresh weight (14.28 g) and dry weight (6.58 g) were recorded by T_4 (75% shade) which was followed by T_2 (25% shade).

Data furnished in Table 24 throw light on fresh and dry weight of *T. arjuna* seedlings. The treatments did not produce any significant effect on the biomass production till the end of the eighth month of the study. The treatments differ significantly during the ninth and tenth month. At the end of tenth month, treatment T_4 (75% shade) was found to be superior while T_1 (0% shade) was inferior with regard to this parameter.

4.4 Effect of shade on physiological growth attributes

4.4.1 Chlorophyll content

Data furnished in Table 25 indicate that in *T. tomentosa*, no trend could be observed with regard to chlorophyll content between different treatments. However, close perusal of the data reveal that the treatment T_4 (75% shade) recorded a high content of chlorophyll a at initial stage (8.16mg g^{-1}) and at the end of the study (4.83

Table 22. Effect of shade on weight (g) of roots of seedlings of *Terminalia tomentosa* at monthly intervals

Treatment number	Treatment details	Age (months after planting)																			
		1		2		3		4		5		6		7		8		9		10	
		FW	DW	FW	DW	FW	DW	FW	DW	FW	DW	FW	DW	FW	DW	FW	DW	FW	DW	FW	DW
T_1	0 per cent shade	3.20	1.06	4.54	1.56	6.61	2.82	15.81^{a}	5.67^{a}	12.18^{b}	5.51^{b}	13.22^{b}	4.76^{b}	18.51^{a}	7.20^{a}	20.10^{a}	7.06^{a}	25.43^{b}	6.15^{a}	25.50^{b}	6.55^{ab}
T_2	25 per cent shade	2.72	1.03	4.53	1.58	5.44	2.50	15.88^{a}	5.29^{a}	13.82^{b}	4.23^{d}	13.15^{b}	4.78^{b}	18.64^{a}	6.46^{b}	18.76^{ab}	6.47^{b}	22.05^{c}	5.32^{b}	23.37^{b}	6.23^{b}
T_3	50 per cent shade	3.37	1.16	4.64	1.61	5.62	2.27	11.94^{b}	2.83^{b}	16.82^{a}	7.34^{a}	17.21^{a}	6.64^{a}	18.72^{a}	7.15^{a}	19.19^{a}	6.97^{ab}	30.59^{a}	6.27^{a}	35.98^{a}	7.01^{a}
T_4	75 per cent shade	3.19	1.11	3.68	1.34	5.08	2.34	15.69^{a}	5.45^{a}	12.31^{b}	4.64^{c}	12.97^{b}	4.81^{b}	16.77^{b}	3.83^{c}	17.18^{b}	5.82^{c}	24.32^{b}	5.99^{a}	26.11^{b}	6.94^{a}
F test		NS	NS	NS	NS	NS	NS	**	**	**	**	**	**	**	**	**	**	**	**	**	**
SEm±		0.33	0.11	0.44	0.17	0.55	0.27	0.40	0.11	0.68	0.08	0.57	0.11	0.24	0.10	0.50	0.15	0.51	0.09	1.37	0.15

NS – Not significant ** Significant at 1 per cent level FW - Fresh weight DW – Dry weight
Figures with similar letters as superscript do not differ significantly

Table 23.Effect of shade on weight (g) of roots of seedlings of *Terminalia bellirica* at monthly intervals

eat-ent nber	Treat-ment details	Age (months after planting)																			
		1		2		3		4		5		6		7		8		9		10	
		F W	DW	F W	DW	F W	DW	FW	DW	F W	DW	F W	DW	F W	DW	F W	DW	F W	DW	F W	
T_1	0 per cent shade	1.65	0.29	2.71	1.59	4.91	1.89	6.40	2.21	6.84	1.79	8.47^{b}	3.64^{d}	8.53^{bc}	2.79^{b}	9.73^{b}	3.53^{b}	10.15^{b}	6.36^{ab}	13.62	
T_2	25 per cent shade	1.77	0.31	2.45	0.48	4.22	1.76	6.33	2.34	7.77	2.02	8.64^{b}	4.26^{b}	8.31^{c}	2.46^{b}	9.95^{b}	3.42^{b}	10.58^{b}	6.27^{b}	12.06	
T_3	50 per cent shade	1.69	0.26	2.38	0.55	4.40	1.84	6.47	2.85	7.78	1.99	10.34^{a}	4.68^{a}	10.78^{a}	3.97^{a}	11.56^{b}	3.86^{b}	12.31^{a}	6.56^{ab}	13.75	
T_4	75 per cent shade	1.76	0.43	2.80	0.72	4.39	1.51	5.66	2.15	7.00	1.98	8.31^{b}	3.19^{c}	10.02^{ab}	2.95^{b}	13.93^{a}	5.04^{a}	13.34^{a}	6.65^{a}	13.67	
st		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	**	**	**	**	**	**	**	NS	
n±		0.14	0.12	0.15	0.24	0.46	0.16	0.57	0.15	0.45	0.11	0.35	0.10	0.422	0.26	0.57	0.44	0.42	0.08	0.95	

– Not significant ** Significant at 1 per cent level FW - Fresh weight DW – Dry weight

ures with similar letters as superscript do not differ significantly

Table 24. Effect of shade on weight (g) of roots of seedlings of *Terminalia arjuna* at monthly intervals

Treat-ment number	Treat-ment details	Age (months after planting)																			
		1		2		3		4		5		6		7		8		9		10	
		F W	DW	F W	DW	F W	DW	FW	DW	F W	DW	F W	DW	F W	DW	F W	DW	F W	DW	F W	DW
T_1	0 per cent shade	2.71	0.76	2.55	0.91	2.79	1.00	5.91	2.01	10.72	4.28	11.69	5.00	11.59	2.36	8.91	3.57	9.63^{b}	5.65^{b}	11.29^{c}	5.48^{c}
T_2	25 per cent shade	2.45	0.88	2.49	0.95	2.95	1.09	5.63	1.88	10.96	4.34	12.13	4.60	14.23	2.50	9.44	3.56	12.16^{b}	5.87^{ab}	16.39^{ab}	6.57^{ab}
T_3	50 per cent shade	2.26	0.94	2.72	0.96	3.15	1.08	5.60	1.88	9.52	3.85	12.23	4.69	14.25	2.99	9.20	3.65	11.41^{b}	6.09^{ab}	13.82^{bc}	5.70^{bc}
T_4	75 per cent shade	2.63	0.83	2.52	0.94	2.96	0.98	5.45	1.82	9.76	3.82	12.42	4.73	15.45	3.51	11.35	3.81	15.61^{a}	6.37^{a}	18.82^{a}	6.86^{a}
test		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	**	**	**
Em±		0.27	0.04	0.26	0.03	0.07	0.04	0.15	0.04	0.33	0.13	0.94	0.08	1.32	0.71	1.10	0.27	0.82	0.13	0.76	0.27

NS – Not significant ** Significant at 1 per cent level FW - Fresh weight DW – Dry weight
Figures with similar letters as superscript do not differ significantly

Table 25. Effect of shade on chlorophyll content (mg g^{-1}) of seedlings of *Treminalia tomentosa* at various stages of growth

Treatment number	Treatment details	Months								
		First month			Fifth month			Tenth month		
		Chlorophyll a	Chlorophyll b	Total chlorophyll	Chlorophyll a	Chlorophyll b	Total chlorophyll	Chlorophyll a	Chlorophyll b	Total chlorophyll
T_1	0 per cent shade	4.46	2.86	3.64	5.56	3.19	4.21	3.07	1.86	3.42
T_2	25 per cent shade	3.10	2.11	2.65	5.20	3.24	4.17	3.78	2.26	2.42
T_3	50 per cent shade	1.40	1.45	1.63	4.18	249	3.26	3.44	1.78	2.44
T_4	75 per cent shade	8.16	3.63	5.25	5.07	3.03	3.95	4.83	2.50	2.94

mg g^{-1}). Generally, all the treatments recorded an increase in chlorophyll a content by the middle of the study which gradually declined towards the end.

A perusal of data also showed that in most of the treatments, chlorophyll b content increased in the fifth month and decreased in the next five months except in T_4 (75% shade). The maximum and minimum content at the beginning of the study was recorded by treatments T_4 (75% shade) and T_3 (50% shade) respectively. This trend was followed till the end of the study.

On examining the data furnished in Table 25, it is also evident that total chlorophyll content of *T. tomentosa* increased up to fifth month except in treatment T_4 (75% shade). In the next five months, there was a decrease in the total chlorophyll content of seedlings in all the treatments. At the beginning of the study, maximum total chlorophyll content was recorded by treatment T_4 (75% shade – 5.25 mg g^{-1}) and the minimum content of 1.63 mg g^{-1} was recorded by treatment T_3 (50% shade). The maximum content at the end of the study (3.42 mg g^{-1}) was recorded by treatment T_1 (0% shade).

In *T. bellirica* (Table 26) also, no uniform trend was noticed with regard to different factions of chlorophyll. In all the treatments except T_3 (50% shade), the chlorophyll a content decreased as the study progressed. All the fractions of chlorophyll was found to be higher in T_4 (75% shade). At the end of the study, plants raised under 50 per cent shade recorded the lowest value (2.83 mg g^{-1}) followed by plants raised under open conditions (2.96 mg g^{-1}).

The chlorophyll b content gradually increased in the mid of the study and subsequently decreased towards the end. The highest content of chlorophyll b was

Table 26. Effect of shade on chlorophyll content (mg g^{-1}) of seedlings of *Treminalia bellirica* at various stages of growth

Treat-ment number	Treat-ment details	Months								
		First month			Fifth month			Tenth month		
		Chlorophyll a	Chlorophyll b	Total chlorophyll	Chlorophyll a	Chlorophyll b	Total chlorophyll	Chlorophyll a	Chlorophyll b	Total Chlorophyll
T_1	0 per cent shade	4.08	2.46	3.19	4.05	3.30	3.94	2.96	1.44	2.01
T_2	25 per cent shade	4.70	2.37	3.54	4.13	2.52	3.26	3.03	1.57	2.14
T_3	50 per cent shade	3.92	2.22	2.94	4.18	2.68	3.41	2.83	1.70	2.21
T_4	75 per cent shade	6.89	2.56	3.98	6.51	3.85	5.04	5.59	3.41	4.42

recorded by T_4 (75% shade) during the initial, middle and final months of observation. Similarly the lowest values were recorded by seedlings grown in treatment T_3 (50% shade) during the initial months, T_2 (25% shade) during the middle and T_1 (0 %shade) towards the end of the study.

The total chlorophyll content of *T. bellirica* did not follow any general trend during the course of investigation (Table 26). The content generally increased during the first half of the study, but later declined during the second half except in T_2 (25% shade) where it continuously decreased. The maximum content of total chlorophyll was shown by T_4 (75% shade) during the entire course of investigation.

Like *T. bellirica*, in *T. arjuna* also no uniformity in trend was seen with regard to the parameter (Table27). In most of the treatments, chlorophyll content increased towards the middle of the study and decreased towards the end. The highest (4.67 mg g^{-1}) and the lowest (2.04 mg g^{-1}) values with regard to chlorophyll a content in the initial stages were shown by treatments T_4 (75% shade) and T_3 (50%shade) respectively. At the end of the study, maximum chlorophyll a content of 5.14 mg g^{-1} was recorded by seedlings grown in treatment T_4 (75% shade) while lowest content of 2.54 mg g^{-1} was recorded by treatment T_1 (0 %shade).

The highest values with regard to chlorophyll b during the initial and final stages were shown by T_4 (75 % shade). Seedlings grown in full sunlight recorded lowest content of chlorophyll b at the end of the study.

The total chlorophyll content of *T. arjuna* increased during the first half and decreased in the second half except in treatment T_4 (75 %shade), where it

Table 27. Effect of shade on chlorophyll content (mg g^{-1}) of seedlings of *Treminalia arjuna* at various stages of growth

Treatment number	Treatment details	Months								
		First month			Fifth month			Tenth month		
		Chlorophyll a	Chlorophyll b	Total chlorophyll	Chlorophyll a	Chlorophyll b	Total chlorophyll	Chlorophyll a	Chlorophyll b	Total chlorophyll
T_1	0 per cent shade	4.05	2.28	3.03	4.67	2.68	3.54	2.54	1.59	2.04
T_2	25 per cent shade	3.61	2.02	2.69	5.85	3.57	4.62	3.99	2.28	3.02
T_3	50 per cent shade	2.04	1.66	1.98	5.95	3.54	4.62	4.55	3.03	3.82
T_4	75 per cent shade	4.67	2.79	3.64	4.14	3.25	3.91	5.14	3.23	4.14

increased throughout the study period. The maximum values (4.67 mg g^{-1} and 4.14 mg g^{-1}), were shown by T_4 in the beginning and at the end of the study.

4.4.2 Stomatal distribution

In all the three species studied, the number of stomata did not show any uniform trend due to shade effect as is evident from the data furnished from Tables 28 to 30. The highest number of stomata in *T. tomentosa* (44586 per cm^2) was recorded by the seedlings grown under T_1 (0% shade) at the end of the study, while the lowest (20700 per cm^2) by seedlings grown under T_4 (75% shade).

In *T. bellirica*, the maximum number of stomata was recorded by T_1 (0% shade) during the entire course of the study (Table 29). The lowest number of stomata (14331 per cm^2) was recorded by T_4 (75% shade), during the fifth month of observation. However, towards the end of the study, the lowest number (17719 per cm^2) of stomata was recorded by T_3 (50% shade).

In *T. arjuna*, data furnished in Table 30 indicate that stomatal number was highest in T_1 (0% shade) during the entire period of observation. However, the minimum number was recorded by T_3 (50% shade), both at the beginning and at the end of the study.

4.5 Effect of shade on nutrient content

4.5.1 Nitrogen

The treatments were seen to exert significant effect on the nitrogen content of all the three species viz. *T. tomentosa, T. bellirica* and *T. arjuna*. The effect of shade on nitrogen content of seedlings of the three species at the end of the study is illustrated in Figure 7. The seedlings of *T. tomentosa*, grown in treatment T_4 (75%

Table 28. Effect of shade on the stomatal distribution (No/ $cm^{2)}$ of seedlings of *Terminalia tomentosa* at various stages of growth

Treat-ment number	Treat-ment details	Months		
		First month	Fifth month	Tenth month
T_1	0 per cent shade	39809	41401	44586
T_2	25 per cent shade	29459	28662	29459
T_3	50 per cent shade	27866	25478	29013
T_4	75 per cent shade	20700	19905	20700

Table 29. Effect of shade on the stomatal distribution (No/ cm^2) of seedlings of *Treminalia bellirica* at various stages of growth

Treat-ment number	Treat-ment details	Months		
		First month	Fifth month	Tenth month
T_1	0 per cent shade	19108	19905	19108
T_2	25 per cent shade	17516	18312	18312
T_3	50 per cent shade	17516	15929	17719
T_4	75 per cent shade	15924	14331	17516

Table 30. Effect of shade on the stomatal distribution (No/ cm^2) of seedlings of *Terminalia arjuna* at various stages of growth

Treat-ment number	Treat-ment details	Months		
		First month	Fifth month	Tenth month
T_1	0 per cent shade	44586	45382	46975
T_2	25 per cent shade	41401	40605	39809
T_3	50 per cent shade	34236	34013	32643
T_4	75 per cent shade	35828	37420	37420

shade) recorded maximum concentration of nitrogen (3.36%) during the initial and middle stages of the study (Table 31). The seedlings grown under T_2 (25% shade) recorded the highest value of 2.38 per cent at the end of the study, followed by T_4 (75% shade - 2.14%). The minimum concentration (1.82%) was shown by T_1 (0% shade) and T_3 (50% shade) at the end of the study. In general, the concentration of nitrogen decreased towards the end of the study, the maximum decrease in nitrogen content was observed in seedlings grown under T_3 (50% shade).

The seedlings of *T. bellirica* also showed a decreasing trend in nitrogen concentration towards the end of the study as is evident from the data furnished in Table 32. At the end of the study, maximum concentration of nitrogen (3.08%) was recorded by T_4 (75% shade) followed by T_3 (50% shade) and T_1 (0% shade), while the lowest nitrogen concentration of 1.68 per cent was recorded by T_2 (25% shade).

The nitrogen concentration of *T. arjuna* (Table 33) also showed a gradual decline towards the end of the study, except in treatment T_2 (25% shade), where it increased gradually. The nitrogen concentration ranged from 1.40 per cent (0% shade) to 2.60 per cent (25% shade) at the end of the study.

4.5.2 Phosphorous

In *T. tomentosa*, there was significant variation between various treatments with regard to phosphorous concentration as affected by shade (Table 31). The effect of shade on phosphorous concentration at the end of the study is shown in Figure 8. In general, the P content declined towards the end of the study in T_1 (0% shade) and T_2 (25% shade). Similarly tissue concentration of phosphorous in plants grown under treatment T_3 (50% shade) increased in the fifth month and decreased towards the end.

Table 31. Effect of shade on the nutrient content of seedlings of *Terminalia tomentosa* at various stages of growth

Treatment number	Treatment details	N %			P %			K %		
		Months			Months			Months		
		First month	Fifth month	Tenth month	First month	Fifth month	Tenth month	First month	Fifth month	Tenth month
T_1	0 per cent shade	2.38^{c}	2.21^{b}	1.82^{b}	0.36^{b}	0.26^{b}	0.25^{b}	0.29^{b}	0.24^{ab}	0.21^{c}
T_2	25 per cent shade	2.94^{b}	2.52^{a}	2.38^{a}	0.50^{a}	0.37^{a}	0.31^{a}	0.25^{c}	0.21^{b}	0.24^{ab}
T_3	50 per cent shade	3.22^{ab}	2.50^{a}	1.82^{b}	0.28^{b}	0.29^{b}	0.27^{b}	0.35^{a}	0.22^{ab}	0.25^{a}
T_4	75 per cent shade	3.36^{a}	2.53^{a}	2.14^{ab}	0.27^{c}	0.28^{b}	0.28^{ab}	0.29^{b}	0.25^{a}	0.22^{bc}
F test		**	*	**	**	**	**	**	**	**
SEm±		0.11	0.07	0.09	0.02	0.01	0.01	0.01	0.02	0.01

NS – Not significant ** Significant at 1 per cent level * Significant at 5 per cent level
Figures with similar letters as superscript do not differ significantly

Table 32. Effect of shade on the nutrient content of seedlings of *Terminalia bellirica* at various stages of growth

Treatment number	Treatment details	N %			P %			K %		
		Months			Months			Months		
		First month	Fifth month	Tenth month	First month	Fifth month	Tenth month	First month	Fifth month	Tenth month
T_1	0 per cent shade	2.80^{b}	2.24^{b}	1.96^{b}	0.19^{c}	0.20^{b}	0.19^{b}	0.26^{b}	0.23^{b}	0.19^{c}
T_2	25 per cent shade	2.80^{b}	2.10^{b}	1.68^{c}	0.37^{b}	0.35^{a}	0.23^{a}	0.28^{b}	0.25^{b}	0.20^{bc}
T_3	50 per cent shade	2.38^{c}	2.24^{b}	2.10^{b}	0.44^{a}	0.36^{a}	0.26^{a}	0.33^{a}	0.32^{a}	0.26^{a}
T_4	75 per cent shade	3.22^{a}	3.08^{a}	3.08^{a}	0.18^{c}	0.22^{b}	0.24^{a}	0.29^{b}	0.26^{b}	0.23^{ab}
F test		**	**	**	**	**	**	**	**	**
SEm±		0.08	0.07	0.05	0.01	0.01	0.01	0.01	0.01	0.01

NS – Not significant ** Significant at 1 per cent level
Figures with similar letters as superscript do not differ significantly

Table 33. Effect of shade on the nutrient content of seedlings of *Terminalia arjuna* at various stages of growth

Treatment number	Treatment details	N %			P %			K %		
		Months			Months			Months		
		First month	Fifth month	Tenth month	First month	Fifth month	Tenth month	First month	Fifth month	Tenth month
T_1	0 per cent shade	2.24^{b}	1.82^{d}	1.40^{c}	0.24^{a}	0.21^{c}	0.19^{c}	0.33^{b}	0.32^{a}	0.19^{b}
T_2	25 per cent shade	2.38^{b}	2.66^{b}	2.60^{a}	0.24^{a}	0.25^{a}	0.30^{a}	0.35^{ab}	0.31^{a}	0.24^{a}
T_3	50 per cent shade	2.39^{b}	2.14^{c}	2.14^{b}	0.21^{a}	0.20^{c}	0.20^{c}	0.37^{a}	0.32^{a}	0.24^{a}
T_4	75 per cent shade	3.50^{a}	2.94^{a}	2.38^{ab}	0.22^{a}	0.23^{b}	0.25^{b}	0.36^{ab}	0.31^{a}	0.21^{ab}
F test		**	**	**	**	*	**	**	NS	**
SEm±		0.05	0.07	0.10	0.01	0.01	0.01	0.01	0.01	0.01

NS – Not significant ** Significant at 1 per cent level * Significant at 5 per cent level
Figures with similar letters as superscript do not differ significantly

However in T_4 (75% shade), the P content increased slightly towards the middle and remained the same at the end. The highest phosphorous concentration was shown by seedlings raised in T_2 (0.37%) followed by T_3 (0.29%), T_4 (0.28%) and T_1 (0.26%).

Data tabulated in Table 32 reveal that phosphorous content in seedlings of *T. bellirica* also varied significantly in relation to intensity of shade. The maximum content at the end of the study was shown by T_3 (50% shade) followed by T_4 (75% shade), T_2 (25% shade) and T_1 (0% shade). There were not many changes in phosphorous concentration in T_1 (0% shade) but the values decreased in T_2 and T_3 (50% shade).

The phosphorous concentration in *T. arjuna* (Table 33) showed significant difference between the treatments due to shade. There was an increase in P content in T_2 (25% shade) and T_4 (75% shade) as the study progressed. However, the concentration declined in T_1 (0% shade) and T_3 (50% shade). At the end of the study, maximum concentration of 0.30 per cent was shown by treatment T_2 followed by T_4 (0.25%), T_3 (0.20%) and T_1 (0.19%).

4.5.3 Potassium

The effect of shade on potassium content in the seedlings of three species of Terminalias at the end of the study is depicted in Figure 9. The data tabulated in Table 31 reveal that in *T. tomentosa*, with regard to different treatments there was a gradual decline in K content towards the end of the study. The maximum concentration of 0.25 per cent was recorded by T_3 (50% shade) at the end of the study. This was followed by T_2 (25% shade), T_4 (75% shade) and T_1 (0% shade). The

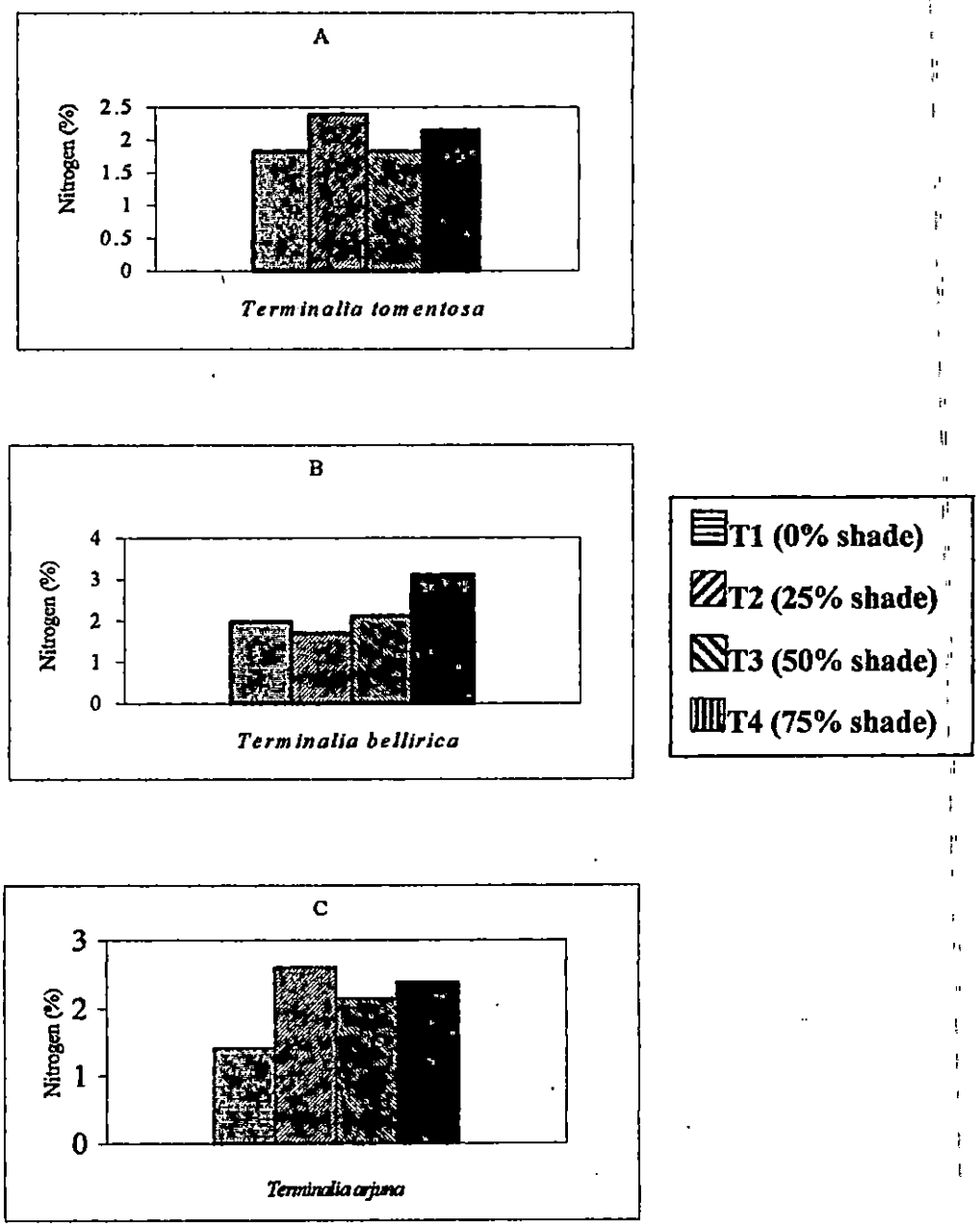

Fig.7. Effect of shade on nitrogen content of Terminalia seedlings

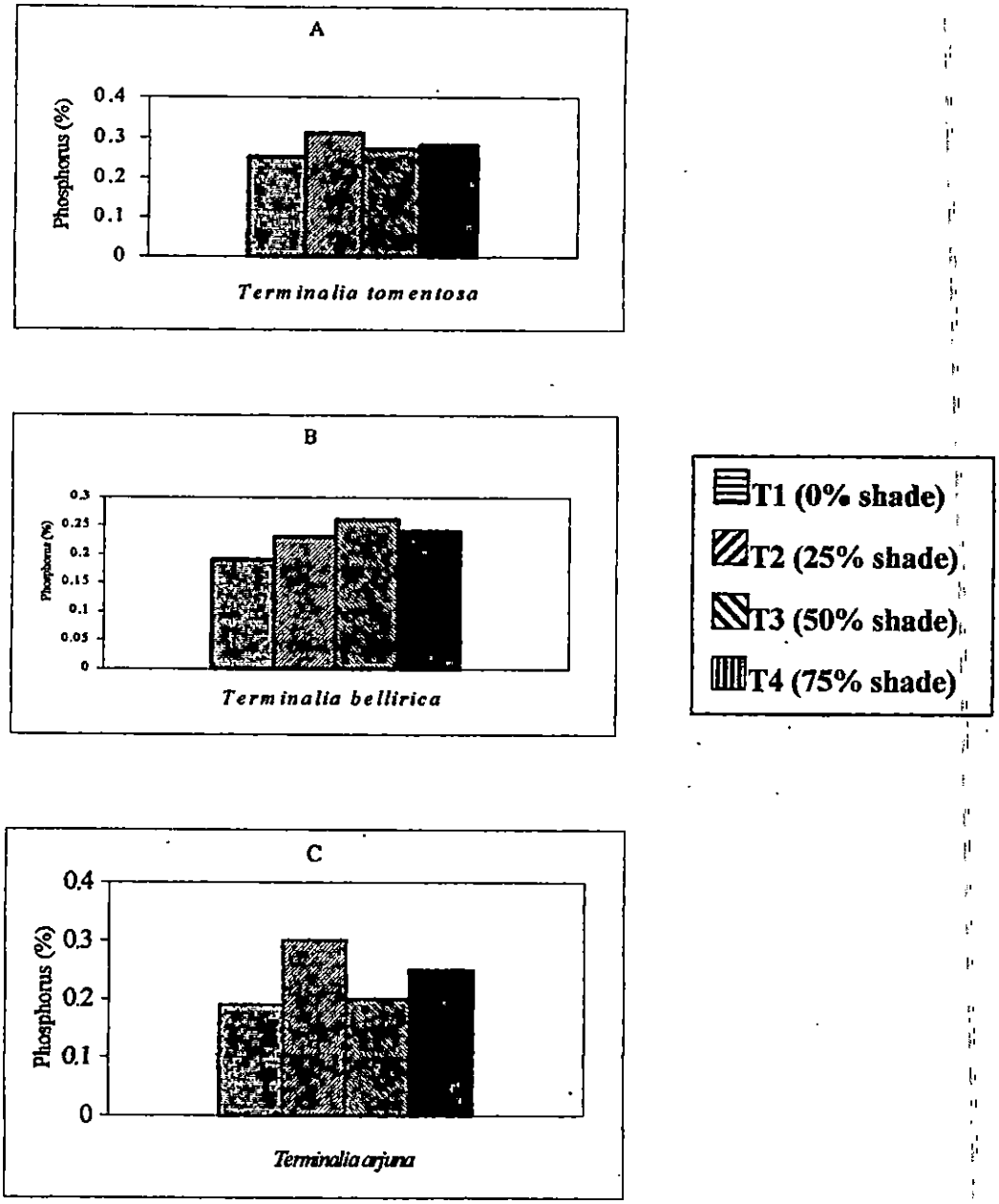

Fig.8. Effect of shade on phosphorous content of Terminalia seedlings

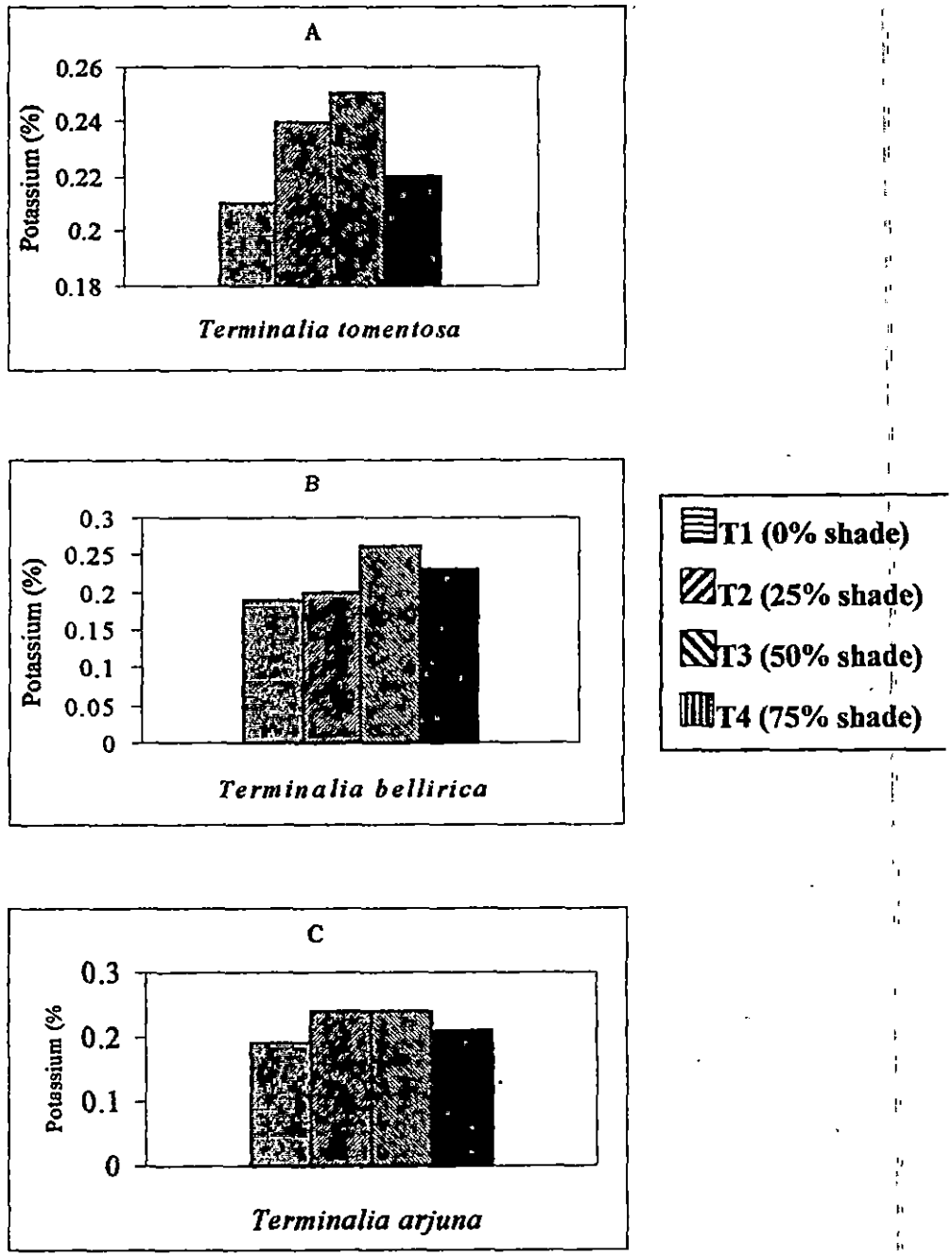

Fig.9. Effect of shade on potassium content of Terminalia seedlings

decrease in concentration was found to be maximum in T_3 (50% shade) and least in treatment T_2 (25% shade).

The concentration of potassium in seedlings of *T. bellirica* was also significantly affected by shade as is evident from the data furnished in Table 32. There was a reduction in concentration of potassium towards the end of the study. The potassium content ranged from 0.26 per cent to 0.33 per cent in treatment T_1 (0% shade) in the beginning and from 0.19 per cent to 0.26 per cent at the end of the study.

The potassium concentration in *T. arjuna* was also affected significantly due to shade during the initial and final stages of the study (Table 33). Like earlier cases here also, the potassium content showed a declining trend towards the end of the study. At the end of the study, the maximum content of 0.24 per cent was shown by treatments T_2 (25% shade) and T_3 (50% shade). This was followed by T_4 (75% shade) and T_1 (0% shade). Similarly, the maximum decrease in concentration of potassium was shown by treatment T_4 (75% shade) while the minimum by T_2 (25% shade).

Discussion

DISCUSSION

Light is one of the inevitable and most dominant factors affecting the plant growth and life activities. Role of light in photo assimilation forms the basis of plant growth and development. Light availability is known to be the dominant resource limiting plant growth, as is evident from the works done on various commercial crops. It is a well established fact that plant species behave differentially to the effect of light and shade. The selection of a plant or tree species for rehabilitation of degraded sites can only be done based on their acclimatization potential to different light levels. Light availability also exerts control over vigour and vitality in a plant community making it an important factor for commercial exploitation of useful species. Silvicultural and agroforestry management tools as affected by light influence not only the regeneration of plants, but also the wildlife habitat. Visual qualities, economic returns and productivity of cultivated lands are also affected by light. Number of research studies are going on to understand the effect of various intensities of light or shade on the growth and productivity of many plants including woody tree seedlings. However, systematic works on tropical commercial timber species which are having multiple uses are very scanty. A thorough understanding of the light requirements of commercial species is also vital for planning the eco-developmental and afforestation activities in any country.

The present series of studies were taken up n the College of Forestry, Vellanikkara, to ascertain the effect of varying intensities of shade on growth and vigour of seedlings of thembavu [*Terminalia tomentosa* var. *crenulata* (Roth.) Cl.],

thanni [*Terminalia bellirica* (Gaertn.) Roxb.] and neermaruthu [*Terminalia arjuna* (Roxb. ex DC.) Wt. & Arn.]. Besides the commercial and medicinal uses, these species are used for extensive planting under social and agroforestry programmes. The salient findings of the studies are discussed here under.

5.1. Effect of shade on shoot growth parameters

5.1.1. Height

In the present study, seedlings of *Terminalia tomentosa* and *Terminalia bellirica* recorded maximum heights of 84.49 cm. and 43.44 cm. respectively, at the end of the study period when grown under 50 per cent shade. It is also evident from the data that the seedlings grown under 25 per cent shade showed significantly lower values, particularly at the end of the study period (66.19 cm). However, the seedlings of *T. tomentosa* grown under 75 per cent shade was showing better performance with regard to height growth in the first half of the study.

Bush and Auken (1987) reported that in *Prosopis glandulosa*, light intensity had substantial relationship with growth of aerial parts of plants, especially at the seedling stage. The effect of shade levels on height growth varies with the nature of species. *Azadirachta indica* seedlings recorded more height growth when grown under full sunlight, whereas seedlings of *Leucaena leucocephala* performed better under 25 per cent shade (Vimal, 1993). Height growth of seedlings of *Dalbergia sisso*, and *Acacia catechu* was found maximum when grown under 50 per cent shade conditions, as against *Casuarina equisetifolia* which performed well under un shaded conditions. (Saxena *et al.*, 1995). Similarly Fairbarian and Neustein (1970) reported that seedlings of *Picea sitchensis, Pseudotsuga menziesii, Tsuga heterophylla, Abies*

grandis, Picea abies and *Abies alba* showed highest shoot growth under 50 per cent shade. *Tilia tomentosa* was also found to record maximum height growth when grown under 50 per cent shade as reported by Lyapova and Palashev (1982). However, *Tectona grandis* and *Grevellia robusta* seedlings performed well under full sunlight conditions (Saju *et al.*, 2000).

The higher growth rate of *T. tomentosa* and *T. bellirica* under 50 per cent shade suggest that these species require medium quantities of sunlight for their height growth. They are light demanders but full sunlight has deterrent effect on the height growth as it results in shortage of moisture within the tissues and higher transpiration losses from the plants. These types of reports were also made by Lyapova and Palashev (1982) in *Tilia tomnetosa* and Filho *et al.* (1997) in *Phyllanthus stipulatus*.

In *T. arjuna*, maximum height growth of 85.65 cm at the end of the study, was recorded by seedlings grown under 75 per cent shade. The performance of these seedlings with regard to height growth when grown under full sunlight was relatively poor. This suggests that the species is more adapted to shade than sunlight. Similar results were observed in *Ailanthus triphysa* in a study conducted by Saju *et al.* (2000). Growth of *Cryptocaria aschersoniana* Menz. seedlings, when grown under different light regimes produced maximum height growth under 90 per cent shade followed by 50 per cent (Rezende *et al.*, 1998). Seedlings of *Picea engelmanni* showed retardation in height growth under shade (Chen, 1997) where as the growth of seedlings of *Quercus lobata, Q. douglasii* and *Q. agrifolia* was not at all influenced by intensity of sunlight (Callaway, 1992). The relatively better height growth of *T. arjuna*

under 75 per cent shade and its height retardation under full sunlight implies that this plant is shade loving in the seedling stage. It can also be seen that, naturally this tree species is widely seen in the riparian habitats, where shade is prevalent (Troup 1921). Generally, it is not found in open and dry areas. Walters and Reich (1996) concluded that height growth and biomass production of seedlings under shade is primarily a function of nature of species.

5.1.2. Collar girth

The study revealed that in *T. tomentosa* and *T. bellirica* shade influenced collar girth during the second half of the study only, unlike *T. arjuna,* where the effect was prominent during most of the study periods. At the end of the study, seedlings of *T. tomentosa* and *T. bellirica* grown under 50 per cent shade recorded maximum growth of 7.46 cm and 6.95 cm respectively. The total girth increment was also maximum when they were grown under 50 per cent shade. An earlier study done in College of Forestry, has revealed that *Leucaena leucocephala* recorded maximum collar girth when grown under 25 per cent and 50 per cent shade levels (Vimal.1993). *Corylus avelana* performed best under 25 per cent and 50 per cent shade levels producing maximum collar girth (Lyapova and Palashev, 1998). As in the case of height growth, seedlings of *T. tomentosa* and *T. bellirica* prefer moderate levels of sunlight for maximum girth growth also.

In *T. arjuna,* there was a significant effect on the girth increment as affected by shade during most of the study period, unlike *T .tomentosa* and *T. bellirica.* Here 75 per cent shade was found to produce maximum girth (8.59 cm) at the end of the study. Similar observations were also made by Saju.*et al.*(1988) in

Ailanthus triphysa and Rezende *et al.* (1998) in *Cryptocaria aschersoniana*. They found that seedlings grown under 90 per cent shade recorded maximum collar girth followed by 50 per cent shade. A study done by Saxena *et al.*(1995) also revealed that in *Dalbergia sisso, Acacia catechu* and *Casuarina equisetifolia,* stem diameter per unit of dry weight of stem was higher when grown under high shade conditions. The shade loving nature of *T .arjuna* could have resulted accumulation of more moisture in the stem, finally leading to larger collar diameter as reported by Carter (1992) in Western Red Cedar (*Thuja plicatus*).

5.1.3 Leaf growth parameters

In all the species viz., *T. tomentosa, T. bellirica* and *T. arjuna,* shade was having a prominent effect on leaf production throughout the period of study. Maximum number of leaves and leaf area was recorded when seedlings were grown under 75 per cent shade. The leaf production and area were found to be directly proportional to shade as is evident from the data. This is in agreement with the results made in *Pinus carveta, Eucalyptus deglupta* and *Khaya grandifolia* seedlings by Wadsworth and Lawton (1968). Similarly, Sharma *et al.*(1994) in *Enicostemma littorale* and Jong *et al.* (1998) in *Orostachys iwarenge* also reported the presence of more number of leaves when grown under higher shade levels. However, Bush and Auken (1987) reported that there was maximum leaf production in *Prosopis glandulosa,* when grown under full sun light. In *Shorea trapezifolia* seedlings, shade was found to have no influence on leaf production (Ashton and Zoysa, 1989). Thus, the variation in responses of each species to shade with regard to leaf growth parameters was also established by earlier workers. At the same time, it can be seen

that in the present study, a higher shade level induced production of larger number of leaves. This probably may be due to the increase in the level of photosynthetic production as a result of more number of photoreceptive units, namely the leaves under shaded conditions. Similar conclusions were also made by Vyas and Nein (1999) in their studies using the seedlings of *Cassia unguistifolia.*

5.2. Effect of shade on root growth parameters

Data related to the root growth parameters viz., length and spread in seedlings of *T. tomentosa* and *T. bellirica* showed that full sunlight generally favored maximum development of roots. Similar results were obtained by Barment (1989) in *Pinus palaustris* and *P. taeda.* Chathurvedi and Bajpai (1999) also recorded maximum root length and spread in seedlings of *Lagerstromia parviflora* and *Wrightia tinctoria* when grown under full sunlight. The higher root growth, when grown under full sunlight conditions may be due to higher allocation of biomass to the underground parts as a result of temperature and sunlight (Reich *et. al.*, 1998).

In *T. arjuna* generally, the root growth parameters recorded were highest when grown under 75 per cent shade. The higher root development under 75 per cent shade in *T. arjuna* may be due the nature of the species and its preference to low temperature. Similar conclusions were also drawn by Chathurvedi and Bajpai (1999) in seedlings of *Bridelia retusa* and *Holarrhena antidysentrica.*

5.3 Effect of shade on biomass production

Biomass of root and shoot portion of seedlings of *T. tomentosa* and *T. bellirica* were substantially higher under 50 per cent shade compared to other treatments particularly at the end of the study. Lyapova and Palashev (1982) in *Tila*

tomentosa, and Pathak *et al.* (1983) in *Lucaena leucocephala* have also observed higher biomass production when grown under 50 per cent shade. Rezende *et al.* (1998) also have made more or less similar observations in *Cryptocaria aschersoniana* seedlings.

The root and shoot biomass production in *T. arjuna* was found to be comparably higher under 75 per cent shade and lowest under 0 per cent shade conditions. Heavy shade is reported to increase the concentrations of nutrients in the foliage (Robert, 1971). The increase in biomass can also be attributed to the production of larger number of side shoots as reported by Yushkov and Zav'yalov (1998). Yoo *et al.* (1997) also reported that in *Hibiscus syriacus*, longer shoots were produced when grown under shade compared to the control plants. This will lead to larger height growth resulting in more stem biomass production.

5.4 Effect of shade on physiological attributes

5.4.1 Chlorophyll content

Data regarding the chlorophyll content of leaves in all the species of Terminalia reveal that chlorophyll a, b and total chlorophyll was slightly higher when grown under 75 per cent shade. No systematic trend in chlorophyll content with regard to various shade levels could be observed in the present study. This was true for all the species studied. However, Gross *et al.* (1996) reported an increase in the chlorophyll content of shaded leaves of Oak (*Quercus* species) compared to open grown saplings. Nygren and Kellomaki (1983) reported an increase in the chlorophyll content in seedlings of *Betula pendula* and *B. pubscens* with increasing shade. As the quantity of light available under shade is less, more photosynthetic pigments are required to trap

the available light. Thus, under shade, plants are adapted to increase the chlorophyll content in order to keep up the carbon assimilation as reported by Niinemets (1997). This view is also supported by the findings of Saju *et al.* (2000). Johnston *et al.* (1998) reported that tropical root crops compensate shade by production of more chlorophyll in leaves, when grown under shaded conditions. Shaded plants normally compensate the reduction in light by an increase in radiation use efficiency i.e. by increasing chlorophyll content in leaves.

5.4.2 Stomatal distribution

In the present study in none of the species, shade was exerting any significant influence on the stomatal distribution. A close perusal of the data indicates that, in all the species, seedlings grown under full sunlight showed maximum number of stomata per cm^2. The maximum stomatal number recorded from *Terminalia tomentosa, T. bellirica* and *T. arjuna* were respectively 44,586 per cm^2, 19,108 per cm^2 and 46,975 per cm^2 when grown under open sunlight. The stomatal frequency was reported to increase in sun grown plants of forest tree species (Lee *et al.*, 1996). Similarly, plants grown under shade were reported to have fewer stomata per unit area of leaf. This type of results was also made by Gross *et al.* (1996) in various plant species.

5.5 Effect of shade on nutrient content

In all the species, the treatments were seen to exert significant effect on nitrogen, phosphorus and potassium concentration. Throughout the study period the nitrogen concentration was found to be maximum when grown under 75 per cent shade. The phosphorous content of seedlings grown under 25 per cent shade was

found to be maximum in *T. tomentosa,* and *T. arjuna* where as in *T. bellirica,* the maximum P concentration was recorded by plants grown under 50 per cent shade. Concentration of potassium in the shoot tissues of *T. tomentosa, T. bellirica* and *T. arjuna* was higher in seedlings grown under 50 per cent shade.

The pattern of nitrogen allotment to tissues as observed in the present study, is in agreement with reports made on *Dicanthium aristatum* by Cruz (1997). The higher concentration of nitrogen under shade is presumed to be due to adaptation of certain plant species to improve the CO_2 assimilation rates on a leaf area basis. Higher nitrogen content in shaded leaves of birch seedlings was also reported by Alphalo and Lehto (1997). Lower shade levels were reported to result more P accumulation in the leaf tissues of *Dicanthium aristatum.* Less accumulation of potassium in plants under shade was reported by Cruz (1997).Variation in species with regard to P and K accumulation was also reported by Lee *et al.* (1996) from their studies using large number of tree species.

Summary

SUMMARY

Sunlight is one of the primary factors influencing the growth and biomass production in green plants. The light requirement of each species varies widely and each species requires specific quantities of sunlight and shade at various stages of their growth period. Light requirement of many annuals including vegetables have been studied well in India and abroad. However, information regarding the effect of light or shade on the growth and vigour of many important commercial forest tree species including Terminalias, particularly in the nursery, are very meager. The wide potentialities of growing trees can be fully exploited, only if a good knowledge about their growth requirements is available.

The present study was carried out in the College of Forestry, Kerala Agricultural University Vellanikkara to evaluate the effect of various shade levels on the growth and vigour of seedlings of Tembavu [*Terminalia tomentosa* var. *crenulata* (Roth.) Cl.], Thanni [*T. bellirica* (Gaertn.) Roxb.] and Neermaruthu [*T. arjuna* (Roxb. ex. DC.) Wt.& Arn.] in the nursery. The salient findings of the experiment are summarized here under.

1. Growth of seedlings of *T. tomentosa*, *T. bellirica* and *T. arjuna* in terms of height was significantly affected by shade during some stages of growth. In *T. tomentosa*, significant effect of shade on height was observed in the second half of the study, while in *T. bellirica* from 6th to 8th month and in *T. arjuna* from 5th to 7th month. Maximum height

growth at the end of the study was recorded for 50 per cent shade in *T. tomentosa* and *T. bellirica*, while 75 per cent performed better in the case of *T. arjuna*.

2. The collar girth of *T. tomentosa* showed significant increase due to 50 per cent shade during 2nd, 3rd, 7th, 8th and 9th month of the study. In *T. bellirica*, girth recorded during 5th, 6th, 8th and 9th month under 50 per cent shade was maximum, while *T. arjuna*, except 1st, 4th and 10th month showed maximum increase in collar girth due to 75 per cent shade.

3. In all the three species viz., *T. tomentosa*, *T. bellirica* and *T. arjuna*, shade exerted prominent effect on leaf production and leaf area throughout the study period. The seedlings grown under 75 per cent shade produced largest number of leaves with maximum leaf area.

4. Generally, the root growth attributes were found to be maximum for seedlings grown under 50 per cent shade in *T. tomentosa* and *T. bellirica* while in *T. arjuna*, the root growth attributes were highest when grown under 75 per cent shade.

5. Root length was significantly affected by shade during 3rd to 6th and 8th month in *T. tomentosa*, 2nd to 5th and 10th month in *T. bellirica* and 4th month onwards in *T. arjuna*. The spread of the roots in *T. tomentosa* during 2nd to 5th month; in *T. bellirica* during 9th and 10th month, and in *T. arjuna* during 4th, 5th, 7th, 8th and 9th month were seen to be influenced by shade significantly.

6. The biomass production of root and shoot portion of the seedlings of *T. tomentosa* and *T. bellirica* was substantially higher when grown under 50 per cent shade, where as 75 per cent shade recorded the higher biomass measurements in *T. arjuna*.

7. No systematic trend in chlorophyll production with regard to various shade levels could be observed in any of the species studied. However, the data pertaining to chlorophyll content of leaves showed that chlorophyll a, chlorophyll b and total chlorophyll content were slightly higher, when seedlings were grown under 75 per cent shade. This was true for all the species studied.

8. Even though there was no significant effect of shade levels on stomatal distribution, generally, in all the species maximum number of stomata was recorded for seedlings grown under full sunlight.

9. In all the species, tissue concentration of nitrogen was found to be highest when seedlings were grown under 75 per cent shade. However, the concentration of phosphorous in seedlings of *T. tomentosa* and *T. arjuna* was found to be highest under 25 per cent shade and that of *T. bellirica* under 50 per cent shade conditions. Unlike nitrogen, concentration of potassium in all the species of Terminalias was generally higher when grown under 50 per cent shade.

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* Originals not seen

EFFECT OF SHADE LEVELS ON GROWTH AND VIGOUR OF SEEDLINGS OF *TERMINALIA* SPECIES IN THE NURSERY

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ABSTRACT OF THE THESIS

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ABSTRACT

The present study was undertaken at the College of Forestry, Kerala Agricultural University, Vellanikkara, Thrissur during the period from 2000 to 2002 to evaluate the effect of various shade levels on the growth and vigour of seedlings of tembavu [*Terminalia tomentosa* var. *crenulata* (Roth.) Cl.], thanni [*T. bellirica* (Gaertn.) Roxb.] and neermaruthu [*T. arjuna* (Roxb. ex DC.) Wt. & Arn.] in the nursery. The study revealed that in general, in all the species examined, shade exerted significant influence on growth and vigour of the seedlings in the nursery.

In *T. tomentosa* and *T. bellirica,* 50 per cent shade produced best results with regard to shoot growth parameters like height and collar girth while in *T. arjuna*, 75 per cent shade was found to be most ideal with regard to these growth parameters. In general, in all the species, seedlings grown under 75 per cent shade produced maximum leaf number and area. The root growth parameters viz., length and spread were found to be the maximum when grown under 50 per cent shade in *T. tomntosa* and *T. bellirica*, while 75 per cent was found to be the best for *T. arjuna*. Similarly, 50 per cent shade was found to be better for *T. bellirica* and *T. tomentosa* with regard to biomass production. However, *T. arjuna* responded well to 75 per cent shade in this regard.

No clear cut trend was seen in the chlorophyll production with regard to the different shade levels in any of the three species studied. However, chlorophyll a, chlorophyll b and total chlorophyll content was slightly higher when grown under 75 per cent shade conditions. The highest number of stomata was seen when the plants

were grown under full sunlight. In all the species, the nitrogen content was found to be highest for seedlings grown under 75 per cent shade while the highest potassium content was recorded when grown under 50 per cent shade. However with regard to the phosphorus concentration, 25 per cent shade was found to perform better in *T. tomentosa* and *T. arjuna* while 50 per cent performed better in *T. bellirica.*