INFLUENCES OF SOIL MOISTURE REGIMES AND STAGE OF HOST INTRODUCTION ON SEEDLING GROWTH OF SANDAL PROVENANCES

By
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THESIS

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DECLARATION

I hereby declare that this thesis entitled "**Influences of soil moisture regimes and stage of host introduction on seedling growth of sandal provenances**" is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any University or Society.

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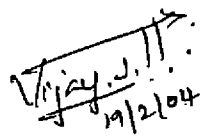

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

Dedicated to…..

Soldiers of Indian Army who have shed their blood to protect Kashmir.

&

My ever loving brother JAGAN

INTRODUCTION

INTRODUCTION

Sandal (*Santalum album* Linn.) occupies a prime position in Indian Forestry and has been rated as the most precious and valuable tree (Srimathi *et al.*, 1995; Radomiljac *et al.*, 1998). Sandal wood has been intimately associated with human civilization since time immemorial and is a part of Indian culture and heritage (Srinivasan *et al.*, 1992).

The scented heartwood of sandal, commercially known as the East Indian Sandalwood, yields the fragrant sandalwood oil on steam distillation. The heartwood of sandal is estimated to be fetching approximately Rs.9 lakhs per tonne in the international market (Ananthapadmanabha, 2000).

The genus *Santalum* is tropical in distribution between 30°N and 40°S from India in the West to Juan Fernandez islands in the East and from Hawaiian Archipelago in the North to New Zealand in the South (Brennan and Merlin, 1993). The widely distributed and economically important genus, *Santalum* consists of 29 species (Hewson and George, 1984), which are xylem tapping root hemi parasites belonging to family Santalaceae. Four *Santalum* species namely *S. spicatum* (R. Br). A.Dc., *S. accuminatum* (R. Br) A.Dc., *S. morrayanum* (Mitchell) C. Gar. and *S. lanceolatum* (R. Br) are native to Western Australia (Sawyer and Jones, 2000).

Among the *Santalum* species, *Santalum album* has the highest oil content (6-7%) while *S. spicatum* (2%) and *S. lanceolatum* (3-5%) yield poorly scented wood and low quality oil (Mc Kinnel, 1990).

In India, nearly 98 per cent (8300 sq. kms) of total sandal area is in Karnataka and Tamil Nadu. In Kerala, natural stand of the tree is present in Marayoor forest area and isolated plants are seen in many homesteads and farmlands.

A growing tree can put an increment of 1 kg of heartwood per year and attain a girth of 1-5 cm per year (Rai, 1990). India exports around 2000 tonnes of wood and 100 tonnes of oil annually to various countries and accounts for 99 per cent of sandalwood oil produced in the world (Lakshmi Sita and Bhattacharya, 1998).

30-60 year old trees having a girth of 40-60 cm generally have the best heartwood suitable for carving as well as for oil extraction (Shankaranarayana *et al.*, 1998). As the oil is present in the heartwood of both the stem and root, the tree is invariably harvested by uprooting. In addition to this the depletion of sandal forest is attributed to factors like illicit felling, disease and smuggling which is very rampant and is the major problem in all the sandal growing states (Nageshwara Rao *et al.*, 1999). Smuggling ultimately results in genetic erosion because smugglers remove genetically superior trees and such populations tend to possess more and more genetically inferior trees (Venkatesan, 1995). Umashankar *et al.* (2000) reported a decline in genetic diversity of natural population due to indiscriminate extraction of sandalwood.

The annual production of sandal wood has declined from 4000 tonnes in 1965-70 to nearly 2000 tonnes during 1999-2000. The oil production has also decreased to 40-50 tonnes during 1999-2000 from 60 tonnes during 1981-1994 (Ananthapadmanabha, 2000).

Establishment of sandal populations were mostly not successful due to various reasons. Being a hemi parasite, the silvicultural requirements are unique and there is no adequate understanding of the same. Sandal has been a component of the traditional agroforestry systems. Its regeneration and establishment has been problematic because of the poor understanding of host-parasite relationships (Surendran *et al.*, 1998). Sandal plants in agroforestry systems may have to tolerate varying levels of competitive and complementary interactions from the component crops. So, an understanding of the complementary and competitive influence of the host on sandal is necessary for successfully growing sandal. When host is introduced in the pot at the early phase, there is possibility of competition for soil moisture and nutrient between sandal and host. There are no reports on the growth responses of sandal under different soil moisture regime. Hence, the present experiment was carried out with the following objectives.

1. To evaluate the seedling growth of sandal provenances under different soil moisture regimes in the presence or absence of host plant.
2. To elucidate the complementary and competitive influences of the stage of introduction of host seedlings on sandal.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Sandal (*Santalum album* Linn.) is a valuable forest tree known for its scented wood. Sandal is a small to medium sized, evergreen hemi parasitic tree with slender drooping branchlets, ordinarily attaining a height of 13.5 m to 16.5 m and a girth of 1.0 m to 1.5 m, though larger specimens are sometimes met with. In natural forests, the tree is observed in dry tropical forests. It is also seen in isolated farms and homesteads in Kerala.

Being a hemi parasite, the establishment of sandal forests were faced with complex problems. Sandal-host relationships, propagation methods, spike disease were the topic of interest for the early sandal researchers. Tree improvement programmes, micropropagation of sandal and establishment of sandal plantations were getting attention in some parts of the world during the last few years. The literatures available on the relevant topics are reviewed in this chapter.

2.1 PROPAGATION

Root suckers are freely produced when the roots are exposed or injured. Young trees coppice fairly well, older trees have little or no coppicing power except on moist ground along the banks of water courses (Troup, 1921). Vegetative propagation is achieved through stem cutting, grafting, air layering or through suckers; but rooting is achieved only in 15-20 per cent of the cuttings (Balasundaran, 1998; Sanjaya *et al.*, 1998).

In *Santalum album* though somatic embryo genesis is reported to be the efficient method of *in vitro* propagation the high per cent of abnormal embryos and poor rate of conversion of somatic embryos to plantlets hinder the efficient utilization of the technique (Ilah *et al.*, 2002).

2.2 SANDAL AND HOST PLANTS

The hemi parasitic nature of sandal was established for the first time by Scott (1871). Later on, the parasitic behaviour of *Santalum* had been described by Barber

(1902 and 1907), Pilger (1935) and Rao (1942). Barber (1902) found an abundance of root connections between sandal seedlings and other plants growing nearby. Rao (1903) and Lushington (1904) also could observe haustoria, which connect sandal roots to host plants and extract nutrients from the host.

The haustoria of sandal, which rise laterally on roots, are exogenous. A young haustorium is formed by the epidermis and cortex of the root (Rao, 1942). According to Pilger (1935) haustoria is derived from the root by the divisions of the cells of pericycle, endodermis and cortex. The young haustoria appear as small hemispherical outgrowths. The free end after coming in contact with the host gradually flattens.

Sandal tree is known to have sent out its roots up to a distance of 30 m for establishing the parasitic relationship (Rai and Sarma, 1986). Rao (1911) reported that the host, which is attacked by sandal, influences the extent and structure of haustoria. Taide (1991) in an anatomical study of sandal haustorium found that the sandal root and the host show direct vascular connections, which later undergoes secondary growth. The vascular connection between the host and sandal becomes so intimate that host root and parasite root becomes almost a single physiological unit, catering to the nutritional requirements of the sandal.

The formation of haustoria is more or less confined to younger roots; the main roots probably take little part in the absorption of nutrients. If no host is met with, the haustoria remain small and ultimately withers away, but if a rootlet of a suitable host is met with, it grows rapidly assuming the shape of flattened bell. The experiments have found that sandal seedlings are incapable of growing beyond a year at the most unless nourished by attachment to the roots of other plants (Rao, 1903).

The obligate parasitic nature of sandal is known since long, but there is no precise information about the nature and degree of its dependence on host.

2.3 SPECIFICITY OF HOST

The presence of favoured host is considered to improve the establishment and growth of sandal. Various researches have identified and classified several hosts of sandal.

Iyengar (1965) has published a list of all known hosts till that time. The sandal hosts have been classified as good, medium and poor based on the complementary influence of the host species on sandal growth (Ananthapadmanabha *et al.*, 1984). In Australia the hosts are generally categorized into three groups namely pot, intermediate and long term hosts (Fox *et al.*, 1990). All the three are critical for adequate survival and growth of sandal at various stages of growth of sandal and at various stages of the plantation growth. Characteristics of suitable pot host include fine root growth and even distribution of roots within the pot, ability to withstand top pruning, low level of competition, low allelopathic influences, low growth structure and persistence in the field after planting out (Fox and Doronila, 1993). Host selection and its management require close investigation, as it is the single most important silvicultural parameter deciding the establishment and growth of sandal plantations. Srinivasan *et al.* (1992) has recommended *Cajanus cajan* as a good primary host for sandal in the seedling stage where as Surendran *et al.* (1998) reported *Albizia saman* as the best life time host for sandal based on growth attributes and amenability for pruning.

In India, earlier researchers have identified a range of pot hosts for the establishment of sandal plantations. The favoured hosts reported are *Desmanthus virgatus* (L.) Willd, *Alternanthera* spp, Forskal, *Crotalaria juncea* in Timor (Surata, 1992), *Calotropis procera* (Aiton) W.T.Aiton, *Cassia siamea* L., *Calliandra calothyrus* Meissn (Shinde *et al.*, 1993), *Cajanus cajan* Huth (Rai, 1990) and *Casurina equisitifolia* (Taide, 1991 and Varghese, 1996).

Radomiljac (1998) reported that considerable variation exists between pot hosts in increasing the sandal survival and growth. Consequently, the utilization of appropriate pot hosts is critical to ensure successful sandal plantation establishment.

Barber (1907) gave a list of 122 species and later Rao (1918) for 144 species of sandal hosts. Out of a large number of associates of sandal, found in its natural habitat, it is difficult to classify the most favorable or suitable host species as sandal may show preference for different plants in different situations.

Establishment of sandal plantations were mostly not successful due to several reasons. Being a semi parasite, the silvicultural requirements are unique and there is no adequate understanding of the same.

Even though many investigations for identifying the best host for sandal in India and other countries are available, the growth stage at which the sandal needs the presence of a host and the complementary and competitive interactions between sandal and the host plants are not available in both India or abroad.

2.4 SANDAL PROVENANCES

Genetic diversity in *Santalum album* is assumed to be imperiled owing to the dysgenic selection and wanton felling perpetrated by smugglers and due to destructive spike disease (Muthana, 1995). Fragmentation of natural sandal population due to excessive human encroachment and land use changes also contributed to the decline of species diversity (Nageshwar Rao *et al.*, 2001).

Sandal is highly polymorphic species (Kulkarni, 1995). Morphological studies have shown that the trees vary significantly in leaf length and breadth, colour of heartwood and in oil content (Bagchi and Veerendra, 1987; Kushalappa, 1983; Kulkarni, 1995). A study of anatomical characteristics viz. xylem cell diameter, epidermal thickness, cortex width and number of vascular bundles has shown that there are genotypic differences in sandal populations (Veerendra and Bagchi, 1986). Prior information on genetic variation, diversity of sandal will assist in valid sampling to capture most of the genetic variation present in natural populations and can hasten progress of both conservation and tree improvement programmes.

Before embarking any tree improvement programme, it is necessary to know the species in detail and its performance in different environments. Such a type of study is more essential in a tree species like *Santalum album* Linn. which has never been subjected to the process of selection and propagation.

As the heartwood formation is genetically controlled, it is desirable to obtain seeds from genetically superior trees for developing a successful artificial regeneration programme and better productivity in sandal (Srinivasan *et al.*, 1992).

Physiological and morphological variations do exist in the sandal seeds collected from different locations (Ramalakshmi and Rangaswamy, 1998). Seed variations may influence the provenance performance and response to the environment (Sindhuveerandra *et al.*, 1998).

Jain *et al.* (1998) identified eight sandal bearing areas as potential provenances based on population density, phenotypic characteristics, latitude, longitude and eco climate. These potential provenances vary in climate and edaphic requirements. They are maintained and protected in collaboration with the respective forest divisions for *in situ* conservation to develop a gene base. Studies are being carried out on soil properties, morphology, phenology, heartwood formation and oil content of these provenances. Seeds are being collected and tested for seed characteristics, viability and germination.

Because of the density of trees and varying intensity of spike disease, sandal populations of Marayoor in Kerala was found to be ideal for experimental studies in sandal (Ghosh *et al.*, 1985). Fifteen trees of reserve 51 of Marayoor range had been selected as candidate plus trees for growth and spike disease evasion (Balasundaran, 1998). These trees have been selected for mass multiplication through tissue culture techniques.

There are no research works done to evaluate the growth rates of various sandal provenances in Kerala.

2.5 THE ROLE OF HOST

The role of host plants in sandal tree, which is having independent root system and evergreen canopy capable of photosynthesizing, has aroused a lot of curiosity among the researchers. There are several reports indicating the necessity of host plants for acquiring some of the plant nutrients by sandal.

Kamalolbhavan (2002) investigated the occurrence of sandal – Arbuscular Mycorrhizal Fungi (AMF) associations in natural sandal growing forests and the response of sandal seedlings to inoculation with commonly available cultures of AMF, shade levels and nature of host in a pot culture experiment.

Srimathi *et al.* (1961) found that leaves of sandal plants did not have the basic amino acids in the absence of host, but when grown with leguminous plants, the sandal leaves showed high concentration of basic amino acids. Therefore, the authors concluded that for the supply of amino acids, sandal plant is dependent on its host. Iyengar (1965) reported that the dependence of sandal on the host is mainly confined to N and P, where as it can directly absorb Ca and K.

Then Rangaswamy *et al.* (1986) suggested that sandalwood depend on its host for P, K and Mg and that in the absence of a host plant, it is incapable of growing normally. Ananthapadmanabha *et al.* (1984) in a pot culture study observed that in many instances sandal seedlings have drawn the nutrients from hosts, but there are instances where some hosts derived benefit from sandal, by getting some amount of P, Ca, Mg. Self-parasitism, a phenomenon in which a plant establishes haustorial connections with the same species was also observed in sandal (Iyengar, 1965).

Comparative analysis of leaves of sandal plants grown independent or with host show appreciable differences in the mineral make up of the leaves. The associations of host brought about higher accumulation of minerals and consequently better growth of sandal plants. In treatments without association of host plants, inspite of higher N content in the leaves, sandal showed poor growth. The experiments further indicated that the sandal plants depend on the host for P, K and Mg, although the plants not associated with hosts are capable of absorbing some minerals, but not enough to sustain growth (Rangaswamy *et al.*, 1986).

2.6 GENETIC IMPROVEMENT IN SANDAL

Tree improvement in sandal mainly aims at evolving trees that can yield more heartwood and oil in a short span of time, coupled with spike disease resistance (Kulkarni *et al.*, 1998). Concentrated efforts have been initiated for the preservation of existing sandal populations and the development of techniques for rapid multiplication of superior disease evaded trees.

Isozyme techniques have been used in *Santalum album* to estimate genetic variations between different populations in Timor (Brand, 1994) and to identify

provenance in West Australia (Egerton-Warburton, 1990). But the pattern of genetic variations within and between sandal populations in India is virtually unknown.

Genetic distance between Indian and Indonesian *Santalum album* populations were analysed using eight major isozyme systems (Fox *et al.*, 1994) and detected a large genetic distance between West Timor and Indian *Santalum album* populations.

Angadi *et al.* (1998) standardised an isozyme technique to identify different provenances of sandal with respect to genetic distance. The variations in peroxidase isozyme pattern of seed tissue of eight provenances of sandal were reported. This help in identifying provenances, characterizing phenotypes, developing a biochemical marker for oil bearing capacity, diagnosing early stage spike diseases and trace element deficiency.

Suma (2002) and Suma and Balasundaran (2003) conducted isozyme and RAPD analysis of eleven natural populations of *Santalum album* in South India that provided vital information regarding the population genetic structure and pattern of genetic diversity.

2.7 INFLUENCE OF WATER STRESS

Water is considered as the most important limiting factor for the establishment and growth of trees in dry areas, which form about 75 per cent of total cultivated area in India. Water deficits can have a major impact on the establishment of seedlings (Stoneman *et al.*, 1994). Water deficits influences all the phases of tree growth and are probably responsible for more growth loss than all other causes combined (Kramer, 1980). The primary effects of water deficits include a decrease in water content and cell turgor of plant tissue and a decrease in the free energy status or potential of remaining water. Tree growth is reduced both directly and indirectly, through effects on cell turgor and indirectly through the intermediation of seed germination, photosynthesis, respiration, mineral nutrition, enzymatic activity, hormone relation, N metabolism etc.

Though some studies on the response of agricultural and horticultural crops to water stress (Giles *et al.*, 1974, Alberte *et al.*, 1977, Evans 1983, Kramer 1983, Turner

et al., 1986, Momen *et al.*, 1992) are available, such studies are limited in forestry species, especially in tropical forestry. The reported findings pertinent to the present investigation are reviewed here.

2.7.1 Growth parameters

Waring and Schlensinger (1985) suggested that decreasing predawn water potential could be well correlated with a decreased tree height at maturity. Water stress was observed to severely depress first year loblolly pine seedling growth and high correlations between growth and soil moisture was found only when soil moisture was limiting (Cannel *et al.*, 1978).

Driessche (1991) observed a drastic reduction in the height; growth and dry weight of *Pseudotusuga menzeisii, Pinus contorta* and P*icea glauca* seedlings in response to water stress.

After the seedling stage the effect of water deficit on shoot growth become more complex and depend mostly on the growth habitat. A summer drought may or may not influence current year height growth depending on when the water stress occur and on the inherent pattern of shoot elongation of the species affected (Kozlowski, 1982).

One of the damaging effects of water stress is the reduction in leaf area, which not only reduces the water loss but also reduces the surface that carries on photosynthesis. Most of the reduction in leaf area because of drought appears to result from slowing cell expansion. Water deficits also reduce leaf area by leaf senescence and inducing early abscission (Ludlow and Muchow 1990).

Restricted water supply caused a five fold reduction in the number of leaves per plant and a reduction of up to 20 per cent in average leaf size in *Eucalyptus maculata* and *E. brockwayi* seedlings (Myers and Landsberg, 1989). Prolonged periodic water shortage reduced the amount of foliage by 90 per cent in *Fagus sylvatica* (Cermak *et al.*, 1993). Rhizopoulou and Davies (1993) observed in *Eucalyptus globulus* that although leaf area of unwatered seedlings was less, the corresponding leaf dry weight was quite similar to that of well watered seedlings.

Greenhouse experiments in *Eucalyptus marginata* seedlings by Stoneman and Dell (1993) indicated that rate of leaf growth was very sensitive to water deficits. The shoot water deficits that develop on hot sunny days are eventually transmitted to the roots through the sap stream.

Water deficits in roots reduce the rate of elongation of roots, root branching and cambial growth. In a study by Pessin (1939) on long leaf and slash pine seedlings, it was evident that root growth is less affected than shoot growth by varying moisture levels. Waring and Schlensinger (1985) cited several experiments suggesting that tree roots do not grow much at soil water potential below seven bars. However, root resumes growth within one or two days after rewatering.

In addition to reduction in root growth, there will be suberisation of roots when water stressed (Kramer, 1969). Even though it is said that water absorption is reduced by suberisation, Chung and Kramer (1975) showed that considerable absorption occurs through suberised roots.

When subjected to restricted water regimes ten week old seedlings of *Acacia mangium* showed an increase in root growth capacity and root/shoot ratio (Awang and Dechavez, 1993). However, in *Picea rubens* Robert and Cannon (1992) observed that drought did not affect the root dry weight or root/shoot ratio.

Drought stimulated the growth of fine roots on the surface and upper soil layers in *Fagus sylvatica* (Cermak *et al.*, 1993). Root growth of unwatered *Eucalyptus globulus* seedlings gradually increased in deeper soil layers where thick root apices and high soil water depletion per unit length was recorded. As a result, the root absorbing surface area was large in unwatered plants as in well watered plants (Rhizopoulou and Davies, 1993).

2.7.2 Dry matter production

Water deficits generally have a negative effect on the dry matter accumulation in plants as it impairs with many of the physiological processes, which determines growth like photosynthesis, respiration, enzyme activity etc. Dry matter production was

significantly affected in four *Acacia* spp when controlled watering was employed (Kireger and Blake, 1994). Water stress reduced dry matter accumulation in *Pseudotsuga menzeisi*, *Pinus contorta* and *Picea glauca* seedlings grown in containerized nursery (Driessche, 1991). Phillips and Riha (1993) reported that above ground biomass accumulation decreased by 21 per cent in the moderately stressed and by 47 per cent in severely stressed seedlings.

2.7.3 Physiological parameters

Water loss from plant tissues alters a number of physiological processes. It causes a loss of turgor inside the cells followed by closure of stomata, alteration of cellular membrane relations, reduction of leaf water potential etc. All these together cause metabolic disruption in plants.

2.7.3.1 Stomatal responses

Stomata begin to close when the turgor of the guard cell decreases. Stomata usually close during relatively early stages of leaf water deficit, often long before leaves wilt (Kozlowski, 1976). The critical leaf water potential for stomatal closure reported for different species should not be taken too seriously because the value varies for different clones and cultivars (Palardy and Kozlowski, 1979) and because the response of stomata to leaf water deficits is modified significantly by factors like internal CO_2 concentration, air humidity, wind, age of leaf, osmotic adjustments etc. (Davies et al., 1974; Kozlowski and Palardy, 1979).

Stomatal conductance has been reported to vary with leaf water potential in several experiments. In *Alnus glutinosa* seedlings, water stressed individuals showed a much lower initial leaf conductance after which it was gradually dropped as leaf water potential decreased (Seiler, 1985). Then Vance and Running (1985) observed that in *Larix occedentalis* seedlings also, minimum stomatal conductance declines with decreasing pre-dawn water status. Ellsworth and Reich (1992) correlated leaf conductance with pre-dawn leaf water potential in *Acer saccharum* seedlings.

Stomatal closure during the middle of the day has been reported for many species of forest trees (Kramer and Kozlowski, 1979; Kozlowski, 1982). Although midday stomatal closure has been attributed to several causes, an important factor in the lag of absorption behind transpiration, which induces leaf dehydration and reduction in leaf water potential to a critical level associated with stomatal closure.

Driessche (1991) observed a reverse trend of increasing stomatal conductance in lodge pole pine seedlings when severe nursery drought was induced.

2.7.3.2 Transpiration rate

The rate of transpiration is directly dependent to the gradient of water vapour between intercellular spaces of the leaf and ambient air. Although high transpiration rate often causes injury, transpiration is unavoidable because of leaf structure favorable for the entrance of CO_2 and for the loss of water vapour (Kozlowski *et al.*, 1991). Stomatal closure was found to be an adaptation mechanism for reduced transpiration rate at water deficit condition (Turner and Kramer, 1980). Under certain conditions, a decrease in the stomatal conductance will reduce the transpiration relatively more than photosynthesis. Transpiration rates were often reduced significantly in certain *Acacia* spp in drier soils (Lange *et al.*, 1987).

2.7.3.3 Leaf temperature

The status of leaf temperature is an indirect measure of plant water stress (Isdo *et al.*, 1978a). When plants were well supplied with water, transpiration would be at the potential rate and the leaves will be relatively cool (Isdo *et al.*, 1978b). They also observed a declining trend in transpiration during moisture deficient situation and the concomitant increase in leaf temperature. Such situation will lead to the reduction in photosynthesis resulting in the decline of total biomass production. Decreasing soil moisture resulted in reduced plant water status and stomatal conductance leading to elevated leaf temperature (Mtui *et al.*, 1981).

2.7.3.4 Plant water potential

A pressure chamber measurement of plant moisture stress provides an estimate of plant water potential. There are many comprehensive studies made on plant

water potential and relevance to water stress (Slatyer 1967, Slavik 1974, Turner and Kramer, 1980).

In many species stomatal resistance to air humidity can be correlated with leaf water potential. A study conducted by Guehl *et al.* (1991) on the leaf gas exchange in response to drought found that stomata closed very rapidly in *Abies bornmulleriana* when water supply is withheld even prior to being any important decrease in leaf predawn water potential.

In *Quercus petreae,* imposed drought caused predawn leaf water potential to reach as low as -2.0 MPa with a progressive decrease in hydraulic conductance. (Breda *et.al.*, 1993). Batten *et al.* (1994) observed a predawn leaf water potential of -0.3 MPa in irrigated trees, whereas it progressively declined to -0.9 MPa in unirrigated trees.

2.7.3.5 Photosynthesis

Any serious interference of water deficit with photosynthesis is likely to significantly reduce the growth. As the leaves become progressively dehydrated, the rate of photosynthesis decrease and eventually the process may stop altogether (Brix, 1972 and 1979). The initial effect of water stress on photosynthesis appears to be one of lowering stomatal conductance in response to low atmospheric humidity (Schulze and Hall, 1982). Although several investigators have shown that increasing water deficits are accompanied by decrease in rate of photosynthesis (Kozlowski 1949, Kriedemann 1971, Brix 1979). There has been controversy about the critical soil moisture at which photosynthesis is first reduced.

A linear relationship was found between soil moisture content and photosynthesis of *Pinus sylvestris* seedlings (Schultz and Gautherum, 1971). Decrease in photosynthesis of P*seudotsuga menzeisii* began when shoot water potential dropped to near -1.0 MPa and at -3.5 MPa, the rate was negligible (Brix, 1972).

Rates of net photosynthesis declined drastically in *Ulmus americana* seedlings with decreasing predawn leaf water status (Walter and Reich, 1989). Net photosynthesis was reduced by 70 per cent in one-year-old containerized *Liriodendron tulupifera*

seedlings when water supply was withheld (Cannon *et al.*, 1993). Photosynthetic rates recovered rapidly following rewatering.

2.8 CHLOROPHYLL CONTENT

In general, chlorophyll content of the leaves reduces with increasing water deficits. Mesophyll cells are more sensitive to water stress and in about 75 per cent of mesophyll cells the chloroplast become swollen under water stress condition (Giles *et al.*, 1974). Chlorophyll content of maize leaves was decreased to almost 60 per cent of control, eight days after irrigation (Alberte *et al.*, 1977).

In *Grevellia robusta* the total chlorophyll, chlorophyll a and chlorophyll b contents decreased with increasing water stress. Synthesis or accumulation of chlorophyll b was found to be more sensitive to water stress when compared to chlorophyll a (Nautiyal *et al.*, 1993). Makhmuda (1983) reported that moisture stress inhibited biosynthesis of the precursor of chlorophyll in wheat leaves, which ultimately reduced the chlorophyll content.

Rajesh (1996) reported that the growth characteristics and physiological behaviour of five species of tree seedlings namely *Acacia mangium, Ailanthus triphysa, Pterocarpus marsupium, Swietenia macrophylla* and *Tectona grandis* most of which were adversely affected due to water stress.

It is evident that, water stress is having a detrimental effect on overall plant growth and survival due to the altered morphological, physiological and biochemical process of the plant. As a general rule, leaf area, shoot growth and root growth are reduced by water stress, root/shoot ratio has been found to increase in certain cases. Many plants respond to low water status by cutting off their transpiration by an active stomatal control and there by maintaining the water potential.

In sandal, the co-habitation with host makes the water stress response more complex. It is not known whether host plants are having a complementary or competitive influence on the internal water status of sandal.

MATERIALS & METHODS

3. MATERIALS AND METHODS

An investigation was carried out at the College of Forestry, Kerala Agricultural University, Vellanikkara, Thrissur on the influences of soil moisture regimes and stage of host introduction on seedling growth of sandal provenances. The experiment was conducted during the months from November 2002 to August 2003.

3.1 CLIMATE AND WEATHER

Geographically the area is located 40 m above mean sea level at 10° 32' N latitude and 76° 26' E longitude. The area experiences warm and humid climate with distinct summer and rainy seasons. The weather data for the experiment period is given in Appendix I.

3.2 METHODOLOGY

Seeds of the two available provenances from Karnataka (Shimoga), and Kerala (Marayoor) were collected and used for the study.

The fleshy exocarp was removed and the seeds were dried for 24 hrs in ambient conditions. Seeds were soaked in 500 ppm gibberlic acid (GA_3) for 15 hours, and were sown in sand in a tray in humid chamber. The trays were irrigated regularly. The germinated seeds were then transplanted to polythene bags (20 cm x 10 cm) filled with potting media, about six weeks after sowing. The composition of the potting media was 1:1:1 sand: soil: FYM. The observations were started 30 days after transplanting the sandal seedlings to the polybags, so that all the seedlings were at two-leaf stage atleast.

Different soil moisture regimes were created in these bags by irrigating them slowly and carefully so that the soil is just saturated and water starts seeping out through the drainage hole provided. Three soil moisture regimes were created by the following irrigation practices.

I_1 - irrigating daily (< 0.003 MPa)

I_2 - irrigating once in three days (0.1 MPa)

I_3 - irrigating once in six days (0.5 MPa)

Depending on the level of the water stress to be imposed irrigation was withheld in selected bags for a day, three days and six days. The water stress cycle continued till the end of the experiment.

As the second part of the study was to evaluate the complementary and competitive influence of the host, the host plants were introduced during the following stages.

H_1 - host planted at the time of planting sandal

H_2 - host planted three months after planting sandal

H_3 - host planted six months after planting sandal

Red gram (*Cajanus cajan* L.,) was used as the host.

The experiment was laid out in completely randomised design replicated three times. There were 18 treatment combinations of the three variables, two provenances, three moisture regimes and three stages of host introduction. Each experimental plot was having 12 seedlings.

Out of the 12 seedlings in each plot, three each were used for destructive sampling and recording observations at 120, 210 and 300 days after planting.

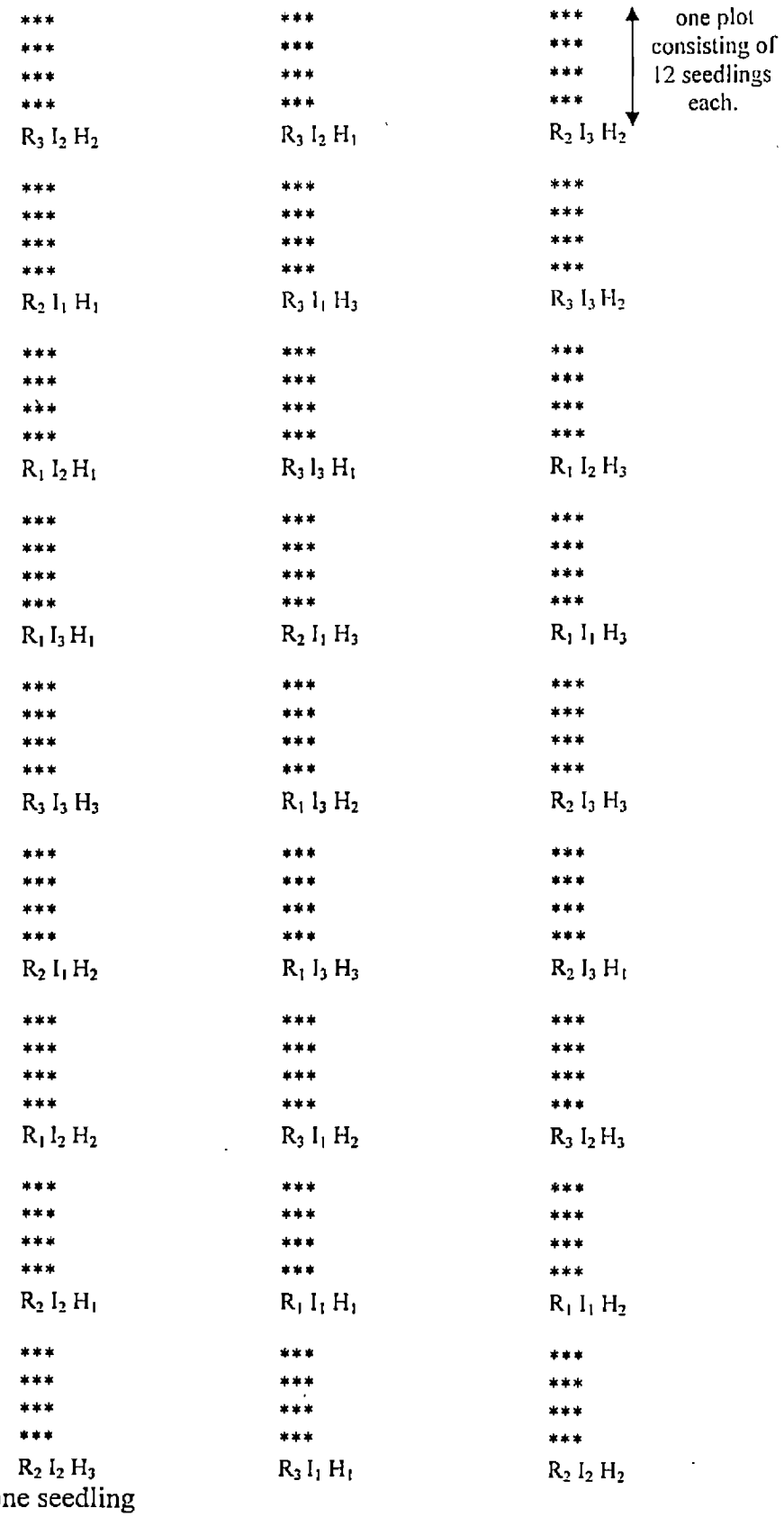
The layout of the experiment is illustrated in Fig. 1.

3.3 OBSERVATIONS

The following observations at various stages of growth of sandal and host were recorded.

3.3.1 Plant height

Height of the sandal seedlings at monthly intervals and the host during destructive sampling (120, 210 and 300 days after planting sandal) were taken from the collar to the tip of the growing point using a meter scale and was expressed in cm.



* represents one seedling

Fig. 1. Lay out of the experiment

3.3.2 Collar diameter

Collar diameter of sandal was measured with the help of a digital Vernier Callipers and expressed in mm

3.3.3 Number of leaves

Every month the number of leaves of all the sandal seedlings was counted separately.

3.3.4 Leaf Area

Leaf area of individual plants of sandal was measured with a Leaf Area Meter (Model L1-300, L1-Cor, Nebraska, USA) and was expressed in cm^2. Three plants per treatment were used for the purpose.

3.3.5 Rooting length

Root length was measured from the collar to the tip of the longest root and the mean was expressed in cm. The same plants that were used to record water potential, leaf area and chlorophyll content was used for the purpose.

3.3.6 Total dry matter

Total dry matter of the plant was calculated by summing the shoot dry weight and root dry weight of each plant.

3.3.7 Haustorial connections

The haustorial connections between sandal and host were observed during every destructive sampling and recorded as number of connections per plant.

3.3.8 Plant water potential

The pre-dawn plant water potential of both sandal seedlings and the hosts, were estimated during 120 DAP, 210 DAP and 300 DAP using a Scholander's pressure bomb type plant water status console (Soil Moisture Equipment Corporation, Ohio, USA) and expressed in MPa. Three plants per treatment were used for the purpose.

3.3.9 Leaf diffusion resistance

A steady state porometer (Model LI-1600, LI-Cor, Nebraska, USA) was used to measure the leaf diffusive resistance (LDR) of the leaves at the end of the water stress cycle. Physiologically mature leaves were selected and the measurements were taken on the abaxial surface. Measurements were made on three plants from each treatment.

Observations were recorded once in three months at 0800 hours and 1400 hours IST to know the pattern of development of stress and were expressed in units of s cm^{-1}.

3.3.10 Transpiration rate

A steady state porometer (Model LI-1600, LI-Cor, Nebraska, USA) was used to measure the transpiration rate of the leaves at the end of the water stress cycle. Physiologically matured leaves were selected and the measurements were taken on the abaxial surface. Measurements were made on three plants from each treatment.

Observations were recorded once in three months at 0800 hours and 1400 hours IST and were expressed in units of $\mu g\ H_2O\ cm^{-2}\ s^{-1}$.

3.3.11 Leaf temperature

Leaf temperature from three plants per treatment was obtained from the same leaf as of diffusion resistance and was expressed in °C.

3.3.12 Chlorophyll content

Chlorophyll content of the leaf was estimated following the method of Starner and Hardley (1967). Leaf samples were cut into pieces and mixed well; 0.1 gm of the sample was weighed into a mortar and ground with a pestle to extract the chlorophyll using 10 ml 80 % acetone. The extract was filtered using Whattman. No. 1 filter paper and made up to 25 ml using 80% acetone. The absorbance was read at 663 nm and 645 nm wavelength in a spectrophotometer. The chlorophyll 'a', chlorophyll 'b' and total chlorophyll of each sample were calculated using the following formula.

Chlorophyll 'a' (mg g^{-1} of tissue) =

[12.7 (OD at 663nm) – (2.69 x OD at 645nm)] x [V / 1000 x W]

Chlorophyll 'b' (mg g^{-1} of tissue) =

[22.9 (OD at 645nm) – (4.68 x OD at 663nm)] x [V / 1000 x W]

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

[20.2 (OD at 645nm) + (8.02 x OD at 663nm)] x [V / 1000 x W]

Where	OD	-	Optical Density or Absorbance
	V	-	Final Volume of 80% acetone extract
	W	-	Fresh weight of tissue in gram

3.4 PLANT NUTRIENT ANALYSIS

The shoot portion of the sample plants at the end of the experiment were analysed for the nutrient content. The plants used for destructive sampling at 102 DAP, 210 DAP and 300 DAP were dried, powdered and digested separately following the wet digestion using concentrated sulphuric acid and 30% hydrogen peroxide (Wolf, 1982). The digest was made up to 50ml and the following nutrients were analysed.

3.4.1 Nitrogen

Nitrogen content in the plant digest was estimated by micro-kjeldhal digestion and distillation method (Jackson, 1958).

3.4.2 Phosphorus

Phosphorus was determined in a known aliquot of the acid extract colorimetrically by the vanado-molybdophosphoric yellow colour method (Jackson, 1958). The yellow colour was read in a spectrophotometer at wavelength of 470 nm.

3.4.3 Potassium

Potassium was estimated in a known volume of acid extract using flame photometer (Jackson, 1958).

3.4.4 Calcium

Calcium was estimated at 422.7 nm in acid extract using Atomic Absorption Spectro photometer.

3.4.5 Sodium

Sodium was estimated in a known volume of acid extract using flame photometer (Jackson, 1958).

3.5 STATISTICAL ANALYSIS

Analysis of variance was performed on the data collected, using statistical package 'MSTAT' (Freed, 1986). The means were compared by using Duncan's Multiple Range Test (DMRT).

RESULTS

4. RESULTS

The influence of water stress and stage of host introduction on seedling growth of sandal (*Santalum album* L.) provenances are presented in this chapter.

4.1 GROWTH PARAMETERS OF SANDAL

4.1.1 Height

The height of sandal seedlings from 30 to 300 DAP are shown in Table 1, 2 and 3 and Fig. 2. The seedlings of Marayoor provenance were taller as compared to Shimoga provenance. The stage of host introduction did not have any significant effect on the height of the sandal seedlings in both the provenances up to 270 DAP. However, in Marayoor provenance at 300 DAP the seedlings were taller when the host was introduced at the time of planting sandal (Plate 1). With the increase in the water stress plant height decreased in Shimoga provenance whereas in Marayoor provenance there was no significant response. The presence of host plant during the early stage of sandal seedlings from 30 to 120 DAP reduced the plant height in both the provenances (Plate 2). The levels of water stress decreased the plant height up to 90 DAP and were significantly different. However, from 120 DAP even though there was a reduction in plant height as the levels of water stress increased they were not significantly different (Table 1).

The interaction effects of stage of host introduction and irrigation levels on the height of sandal seedlings were not significant at any of the stages (Table 2).

Interaction of sandal provenances, hosts and irrigation levels on the seedling height of sandal was not significant in any of the stages from 30 to 300 DAP (Table 3).

4.1.2 Collar diameter

The collar diameter of sandal seedlings from 30 to 300 DAP are shown in Table 4, 5 and 6 and Fig. 3. The seedlings of Marayoor provenance recorded a higher collar diameter as compared to Shimoga provenance throughout the period of the

Table 1. Plant height (cm) of sandal seedlings as affected by stage of host introduction and different levels of water stress

Provenances	Days after planting																			
	30		60		90		120		150		180		210		240		270		300	
	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M
Time of host introduction																				
At the time of planting sandal	9.33[b]	11.29[a]	10.43[c]	12.66[a]	12.10[b]	14.49[a]	13.46	16.63	14.91	18.72	16.43	21.12	18.02[d]	23.33[a]	19.59	25.73	21.33	28.00	24.71	30.41
3 months after planting sandal	9.96[b]	11.87[a]	1.29[bc]	13.41[a]	12.80[b]	15.09[a]	14.16	16.55	15.77	18.04	17.07	19.66	18.14[d]	21.14[b]	19.57	22.56	21.44	24.01	22.97	27.06
6 months after planting sandal	10.16[b]	12.12[a]	11.48[b]	13.62[a]	13.20[b]	15.44[a]	14.62	17.12	16.12	18.99	18.08	20.83	19.77[cd]	22.37[a]	21.21	23.85	22.99	25.46	22.73	25.60
P	0.024		0.011		0.045		NS		NS		NS		NS		NS		NS		NS	
Irrigation																				
Daily	9.91	11.89	11.16	13.45	12.65	15.47	14.28	17.36	16.04	19.19	17.72	21.33	19.32	23.13	20.82	25.03	22.67	27.00	24.49	29.03
Once in three days	9.98	11.43	11.26	12.77	12.91	14.21	14.14	16.14	15.60	17.92	17.31	20.34	18.67	22.11	20.27	24.12	21.97	26.01	23.58	28.09
Once in six days	9.56	11.95	10.79	13.47	12.53	15.34	13.81	16.81	15.46	18.65	16.55	20.04	17.94	21.60	19.28	22.98	20.82	24.46	22.35	25.96
P	NS		NS		NS		NS		NS		NS		NS		NS		NS		NS	
Provenance Mean	9.81	11.75	11.06	13.23	12.69	15.00	14.07	16.76	15.70	18.59	17.19	20.53	18.64	22.28	20.12	24.04	21.87	25.82	23.47	27.69
P	NS		NS		NS		NS		NS		NS		NS		NS		NS		NS	
SEm ±	0.519		0.579		0.696		0.779		0.892		1.021		1.211		1.449		1.661		1.897	

S – Shimoga provenance

M – Marayoor provenance

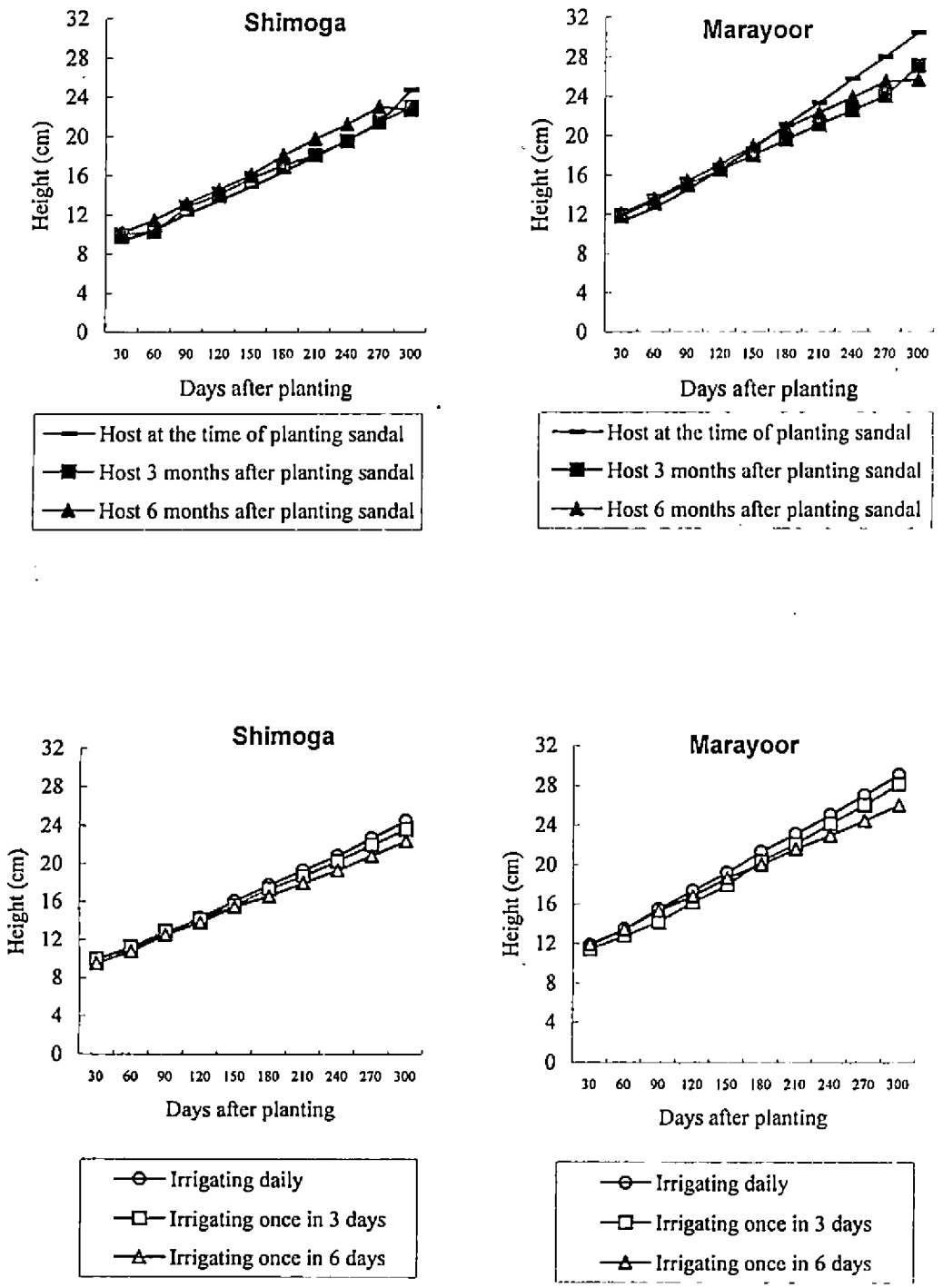


Fig. 2. Height of sandal seedlings in Shimoga and Marayoor provenance as affected by stage of host introduction and levels of water stress

Plate 1. Sandal seedlings of Marayoor provenance at 300 days after planting, when the host was introduced at the time of planting sandal.

Plate 2. Comparison of seedlings of Shimoga and Marayoor provenance with and without host at 120 days after planting.

Table 2. Interaction effects of stage of host introduction and irrigation levels on the height (cm) of sandal seedlings

Stage of host introduction	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
	30 Days after planting				60 Days after planting			
At the time of planting sandal	10.76	9.83	10.34	10.31	12.23	10.97	11.43	11.54
3 months after planting sandal	10.62	10.99	11.14	10.92	12.02	12.31	12.72	12.35
6 months after planting sandal	11.32	11.29	10.80	11.14	12.65	12.75	12.22	12.54
Mean	10.90	10.70	10.76		12.30	12.01	12.12	
P (0.05)	NS				NS			
SEm ±	0.519				0.579			
Stage of Host introduction	90 Days after planting				120 Days after planting			
At the time of planting sandal	14.18	12.37	13.32	13.29	16.00	14.43	14.70	15.04
3 months after planting sandal	13.71	13.65	14.46	13.94	15.43	14.92	15.71	15.35
6 months after planting sandal	14.29	14.66	14.02	14.32	16.02	16.08	16.52	16.21
Mean	14.06	13.56	13.93		15.82	15.14	15.64	
P (0.05)	NS				NS			
SEm ±	0.696				0.779			
Stage of Host introduction	150 Days after planting				180 Days after planting			
At the time of planting sandal	17.82	16.44	16.19	16.82	20.17	18.69	17.47	18.78
3 months after planting sandal	17.20	16.28	17.25	16.91	18.75	17.65	18.70	18.37
6 months after planting sandal	17.83	17.55	17.73	17.70	19.52	19.68	19.17	19.46
Mean	17.62	16.76	17.06		19.48	18.67	18.45	
P (0.05)	NS				NS			
SEm ±	0.892				1.02			
Stage of Host introduction	210 Days after planting				240 Days after planting			
At the time of planting sandal	22.23	20.94	18.86	20.68	24.42	23.33	20.23	22.66
3 months after planting sandal	20.22	18.90	19.82	19.65	21.72	20.27	21.19	21.06
6 months after planting sandal	21.23	21.33	20.64	21.07	22.65	22.97	21.97	22.53
Mean	21.23	20.39	19.77		22.93	22.19	21.13	
P (0.05)	NS				NS			
SEm ±	1.21				1.45			
Stage of Host introduction	270 Days after planting				300 Days after planting			
At the time of planting sandal	26.63	25.79	21.57	24.66	28.66	28.08	23.12	26.62
3 months after planting sandal	23.38	21.69	22.65	22.57	25.22	23.32	23.96	24.17
6 months after planting sandal	24.48	24.48	23.71	24.22	26.18	26.11	25.33	25.87
Mean	24.83	23.99	22.64		26.69	25.84	24.14	
P (0.05)	NS				NS			
SEm ±	1.66				1.89			

Table 3. Interaction effects of provenances, hosts and irrigation levels on height (cm) of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	30 Days after planting				30 Days after planting			
At the time of planting sandal	9.73	9.27	9.00[e]	9.33	11.79	10.39	11.67	11.25
3 months after planting sandal	9.25	10.47	10.17	9.96	11.98	11.51	12.11	11.86
6 months after planting sandal	10.75	10.21	9.52	10.16	11.90	12.38	12.07	12.11
Mean	9.91	9.98	9.56		11.89	11.42	11.95	
P (0.05)	NS							
SEm ±	0.299							
Stage of Host introduction	60 Days after planting				60 Days after planting			
At the time of planting sandal	10.79	10.56	9.94	10.43	13.67	11.38	12.92	12.66
3 months after planting sandal	10.68	11.61	11.59	11.29	13.36	13.01	13.85	13.41
6 months after planting sandal	12.02	11.60	10.83	11.48	13.31	13.92	13.62	13.61
Mean	11.16	11.25	10.78		13.44	12.77	13.46	
P (0.05)	NS							
SEm ±	0.334							
Stage of Host introduction	90 Days after planting				90 Days after planting			
At the time of planting sandal	11.98	12.25	12.06	12.1	16.39	12.49	14.58	14.49
3 months after planting sandal	12.51	12.29	12.89	12.56	14.92	14.31	16.04	15.10
6 months after planting sandal	13.46	13.50	12.63	13.2	15.11	15.82	15.40	15.40
Mean	12.65	12.68	12.53		15.47	14.21	15.34	
P (0.05)	NS							
SEm ±	0.402							
Stage of Host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	13.23	13.80	13.33	13.45	18.77	15.06	16.07	16.63
3 months after planting sandal	14.30	14.10	14.07	14.06	16.57	15.74	17.35	16.55
6 months after planting sandal	15.30	14.53	14.03	14.62	16.73	17.62	17.01	17.12
Mean	14.28	14.14	13.81		17.36	16.14	16.81	
P (0.05)	NS							
SEm ±	0.450							

Contd.

Table 3. Continued

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	150 Days after planting				150 Days after planting			
At the time of planting sandal	14.50	15.50	14.72	14.90	21.13	17.38	17.65	18.72
3 months after planting sandal	16.50	15.22	15.60	15.77	17.90	17.34	18.89	18.04
6 months after planting sandal	17.13	16.07	16.07	16.42	18.53	19.04	19.40	18.99
Mean	16.04	15.59	15.46		19.18	17.92	18.65	
P (0.05)	NS							
SEm ±	0.515							
Stage of Host introduction	180 Days after planting				180 Days after planting			
At the time of planting sandal	16.33	17.23	15.73	16.43	24.00	20.14	19.21	21.11
3 months after planting sandal	18.07	16.47	16.68	17.07	19.43	18.84	20.72	19.66
6 months after planting sandal	18.77	18.23	17.23	18.07	20.27	21.13	21.10	20.83
Mean	17.72	17.31	16.54		21.23	20.03	20.01	
P (0.05)	NS							
SEm ±	0.590							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	18.03	18.90	17.13	18.02	26.43	22.98	20.58	23.33
3 months after planting sandal	19.37	17.43	17.63	18.14	21.07	20.37	22.00	21.14
6 months after planting sandal	20.57	19.68	19.07	19.77	21.90	22.99	22.22	22.37
Mean	19.32	18.67	17.94		23.13	22.11	21.60	
P (0.05)	NS							
SEm ±	0.699							
Stage of Host introduction	240 Days after planting				240 Days after planting			
At the time of planting sandal	19.43	20.83	18.51	19.59	29.40	25.83	21.95	25.72
3 months after planting sandal	21.07	18.83	18.80	19.56	22.37	21.72	23.58	22.55
6 months after planting sandal	21.97	21.13	20.53	21.21	23.33	24.80	23.41	23.84
Mean	20.69	20.26	19.28		25.03	24.11	22.98	
P (0.05)	NS							
SEm ±	0.837							

Contd.

Table 3. Continued

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	270 Days after planting				270 Days after planting			
At the time of planting sandal	21.20	22.92	19.86	21.32	32.07	28.68	23.27	28.04
3 months after planting sandal	22.97	20.18	20.27	21.14	23.80	23.20	25.03	24.01
6 months after planting sandal	23.83	22.80	22.33	22.98	25.12	26.15	25.09	25.45
Mean	22.66	21.96	20.82		26.99	26.01	24.46	
P (0.05)	NS							
SEm ±	0.659							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	23.08	24.51	21.31	22.96	34.66	31.64	24.93	30.41
3 months after planting sandal	24.83	21.95	21.42	22.73	25.63	24.68	26.50	25.60
6 months after planting sandal	25.55	24.28	24.31	24.71	26.81	27.94	26.44	27.06
Mean	24.48	23.58	22.34		29.03	28.08	25.95	
P (0.05)	NS							
SEm ±	1.095							

experiment. The collar diameter showed significant variation due to the stage of host introduction in both the provenances from 30 to 300 DAP. The introduction of host at the time of planting sandal or three months after planting sandal decreased the collar diameter of the sandal seedlings in both the provenances. As the levels of water stress increased, there was a decrease in the collar diameter of the seedlings in both the provenances but were significant only at 270 and 300 DAP. The decrease was more prominent in seedlings watered once in six days as compared to seedlings watered daily and once in three days (Table 4).

The interaction effects of stage of host introduction and irrigation levels on the collar diameter of sandal seedlings was significant from 30 to 240 DAP. At all the stages the seedlings watered daily and host introduced six months after planting sandal showed a higher collar diameter as compared to seedlings watered in other stages of host introduction (Table 5).

Interaction effects of sandal provenances, hosts and irrigation levels on the collar diameter of the seedlings of sandal was not significant in any of the stages from 30 to 300 DAP (Table 6).

4.1.3 Number of leaves

The number of leaves per plant from 30 to 300 DAP are shown in Table 7, 8 and 9 and Fig. 4. Introduction of hosts significantly affected the number of leaves in sandal seedlings at 30 DAP and from 180 to 300 DAP. The host plants decreased the number of leaves in sandal seedlings. This response was consistent from 180 DAP and more prominent in Marayoor provenance. Though the number of leaves were not significantly affected due to water stress up to 150 DAP, it decreased especially in the Shimoga provenance from 180 DAP onwards. The influence of water stress on number of leaves was less prominent in Marayoor during most of the growth period (Table 7).

The interaction effects of stage of host introduction and irrigation levels on the number of leaves of sandal seedlings were significant only from 210 to 300 DAP (Table 8).

Table 4. Collar diameter (mm) of sandal seedlings as affected by stage of host introduction and different levels of water stress

Provenances	Days after planting																			
	30		60		90		120		150		180		210		240		270		300	
	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M
Time of host introduction																				
At the time of planting sandal	1.12^{c}	1.21^{bc}	1.29^{c}	1.46^{bc}	1.42^{d}	1.67^{bc}	1.50^{c}	1.82^{b}	1.59^{c}	1.92^{ab}	1.68^{c}	2.02^{ab}	1.76^{c}	2.11^{ab}	1.82^{d}	2.22^{ab}	1.90^{d}	2.36^{ab}	1.97^{d}	2.46^{ab}
3 months after planting sandal	1.30^{bc}	1.51^{a}	1.45^{bc}	1.70^{a}	1.60^{cd}	1.81^{ab}	1.69^{bc}	1.88^{ab}	1.77^{bc}	1.95^{ab}	1.85^{bc}	2.01^{ab}	1.93^{bc}	2.08^{ab}	2.00^{c}	2.15^{bc}	2.07^{cd}	2.23^{bc}	2.12^{cd}	2.31^{bc}
6 months after planting sandal	1.38^{ab}	1.52^{a}	1.58^{ab}	1.77^{a}	1.70^{bc}	1.97^{a}	1.79^{b}	2.03^{a}	1.87^{b}	2.10^{a}	1.95^{b}	2.19^{a}	2.03^{b}	2.28^{a}	2.10^{bc}	2.38^{a}	2.15^{bc}	2.47^{a}	2.22^{c}	2.58^{a}
P	0.0001		0.0003		0.0005		0.003		0.007		0.011		0.010		0.017		0.044		0.035	
Irrigation																				
Daily	1.31	1.43	1.49	1.64	1.63	1.81	1.72	1.92	1.81	2.01	1.89	2.10	1.98	2.19	2.04	2.29	2.12^{b}	2.41^{a}	2.18^{b}	2.50^{a}
Once in three days	1.29	1.46	1.47	1.71	1.59	1.90	1.69	1.99	1.76	2.06	1.83	2.16	1.90	2.25	1.96	2.35	2.02^{b}	2.46^{a}	2.08^{b}	2.59^{a}
Once in six days	1.2	1.37	1.37	1.58	1.49	1.74	1.57	1.82	1.66	1.90	1.75^{d}	1.97	1.84	2.04	1.90	2.11	1.98^{b}	2.19^{b}	2.05^{b}	2.27^{b}
P	NS		NS		NS		NS		NS		NS		NS		NS		0.043		0.044	
Provenance Mean	1.27	1.44	1.44	1.64	1.57	1.81	1.66	1.91	1.74	1.99	1.83	2.08	1.90	2.16	1.97	2.55	2.04	2.35	2.10	2.45
P(0.05)	NS		NS		NS		NS		NS		NS		NS		NS		NS		NS	
SEm ±	0.103		0.116		0.116		0.116		0.117		0.12		0.121		0.126		0.132		0.135	

S – Shimoga provenance

M – Marayoor provenance

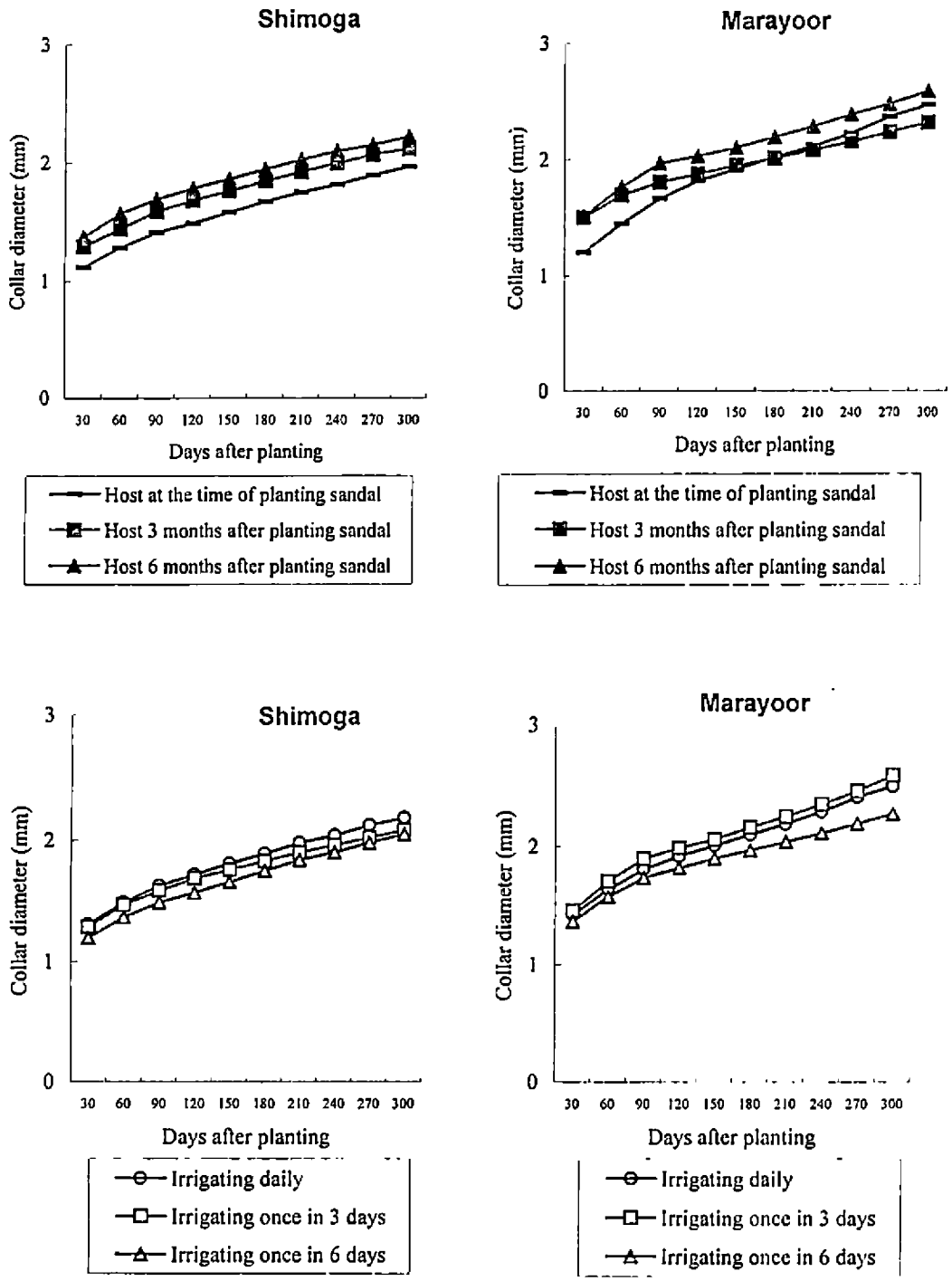


Fig. 3. Collar diameter of sandal seedlings in Shimoga and Marayoor provenance as affected by stage of host introduction and levels of water stress

Table 5. Interaction effects of stage of host introduction and irrigation levels on the collar diameter (mm) of sandal seedlings

Stage of host introduction	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
	30 Days after planting				60 Days after planting			
At the time of planting sandal	1.23^{cd}	1.17^{d}	1.10^{e}	1.17	1.40	1.40	1.33	1.38
3 months after planting sandal	1.28^{c}	1.47^{b}	1.45^{b}	1.40	1.47	1.65	1.67	1.60
6 months after planting sandal	1.59^{a}	1.48^{b}	1.29^{c}	1.45	1.82	1.71	1.47	1.67
Mean	1.37	1.37	1.28		1.56	1.59	1.49	
P (0.05)	0.03				NS			
SEm ±	0.103				0.116			
Stage of Host introduction	90 Days after planting				120 Days after planting			
At the time of planting sandal	1.56^{d}	1.61^{c}	1.46^{e}	1.54	1.71^{cd}	1.72^{cd}	1.55^{e}	1.66
3 months after planting sandal	1.59^{d}	1.78^{b}	1.74^{bc}	1.70	1.68^{d}	1.87^{bc}	1.82^{c}	1.79
6 months after planting sandal	2.01^{a}	1.85^{ab}	1.64^{e}	1.83	2.09^{a}	1.93^{b}	1.72^{cd}	1.91
Mean	1.72	1.75	1.61		1.83	1.84	1.70	
P (0.05)	0.04				0.05			
SEm ±	0.116				0.115			
Stage of Host introduction	150 Days after planting				180 Days after planting			
At the time of planting sandal	1.82^{d}	1.82^{d}	1.63^{f}	1.76	1.91^{d}	1.91^{d}	1.73^{e}	1.85
3 months after planting sandal	1.74^{e}	1.93^{bc}	1.91^{c}	1.86	1.81^{de}	2.00^{c}	1.99^{cd}	1.93
6 months after planting sandal	2.17^{a}	1.99^{b}	1.79^{cd}	1.98	2.27^{a}	2.08^{b}	1.87^{de}	2.07
Mean	1.91	1.91	1.78		2.00	2.00	1.86	
P (0.05)	0.03				0.02			
SEm ±	0.117				0.120			
Stage of Host introduction	210 Days after planting				240 Days after planting			
At the time of planting sandal	1.99^{c}	1.99^{c}	1.81^{e}	1.93	2.09^{bc}	2.09^{bc}	1.88^{d}	2.02
3 months after planting sandal	1.89^{d}	2.08^{b}	2.05^{b}	2.01	1.97^{c}	2.14^{b}	2.11^{bc}	2.07
6 months after planting sandal	2.36^{a}	2.16^{ab}	1.95^{cd}	2.16	2.45^{a}	2.24^{nb}	2.02^{c}	2.24
Mean	2.08	2.08	1.94		2.17	2.16	2.00	
P (0.05)	0.03				0.04			
SEm ±	0.121				0.126			
Stage of Host introduction	270 Days after planting				300 Days after planting			
At the time of planting sandal	2.23	2.19	1.97	2.13	2.31	2.30	2.05	2.22
3 months after planting sandal	2.05	2.21	2.18	2.15	2.12	2.29	2.25	2.22
6 months after planting sandal	2.52	2.32	2.09	2.31	2.60	2.42	2.19	2.40
Mean	2.27	2.24	2.08		2.34	2.34	2.16	
P (0.05)	NS				NS			
SEm ±	0.131				0.135			

Table 6. Interaction effects of provenances, hosts and irrigation levels on collar diameter (mm) of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	30 Days after planting				30 Days after planting			
At the time of planting sandal	1.15	1.15[d]	1.07	1.12	1.31	1.21	1.12	1.21
3 months after planting sandal	1.14	1.42	1.33	1.31	1.42	1.52	1.59	1.51
6 months after planting sandal	1.64	1.32	1.19	1.38	1.54	1.65	1.38	1.52
Mean	1.4	1.30	1.20		1.42	1.46	1.36	
P (0.05)	NS							
SEm ±	0.060							
Stage of Host introduction	60 Days after planting				60 Days after planting			
At the time of planting sandal	1.31	1.34	1.23	1.30	1.49	1.46	1.43	1.46
3 months after planting sandal	1.35	1.52	1.49	1.45	1.58	1.77	1.73	1.71
6 months after planting sandal	1.81	1.53	1.38	1.57	1.83	1.89	1.58	1.77
Mean	1.49	1.46	1.37		1.63	1.71	1.58	
P (0.05)	NS							
SEm ±	0.067							
Stage of Host introduction	90 Days after planting				90 Days after planting			
At the time of planting sandal	1.44	1.50	1.31	1.42	1.68	1.72	1.61	1.67
3 months after planting sandal	1.49	1.66	1.65	1.60	1.68	1.91	1.83	1.81
6 months after planting sandal	1.95	1.62	1.51	1.70	2.06	2.08	1.77	1.97
Mean	1.63	1.59	1.49		1.81	1.90	1.73	
P (0.05)	NS							
SEm ±	0.067							
Stage of Host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	1.53	1.59	1.39	1.50	1.89	1.84	1.72	1.82
3 months after planting sandal	1.59	1.75	1.73	1.69	1.76	1.98	1.91	1.89
6 months after planting sandal	2.05	1.71	1.60	1.79	2.12	2.14	1.83	2.03
Mean	1.72	1.68	1.57		2.00	1.99	1.82	
P (0.05)	NS							
SEm ±	0.067							

Contd.

Table 6. Continued

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	150 Days after planting				150 Days after planting			
At the time of planting sandal	1.61	1.69	1.47	1.59	2.03	1.95	1.79	1.92
3 months after planting sandal	1.68	1.82	1.83	1.78	1.81	2.04	1.99	1.95
6 months after planting sandal	2.13	1.79	1.68	1.87	2.20	2.21	1.90	2.10
Mean	1.81	1.77	1.66		2.01	2.1	1.90	
P (0.05)	NS							
SEm ±	0.068							
Stage of Host introduction	180 Days after planting				180 Days after planting			
At the time of planting sandal	1.69	1.77	1.58	1.68	2.13	2.05	1.88	2.02
3 months after planting sandal	1.75	1.88	1.91	1.85	1.86	2.12	2.06	2.01
6 months after planting sandal	2.23	1.85	1.76	1.95	2.30	2.30	1.97	2.19
Mean	1.89	1.83	1.75		2.1	2.15	1.97	
P (0.05)	NS							
SEm ±	0.070							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	1.76	1.85	1.66	1.76	2.22	2.15	1.96	2.11
3 months after planting sandal	1.85	1.95	1.99	1.93	1.93	2.21	2.11	2.08
6 months after planting sandal	2.32	1.91	1.86	2.03	2.40	2.40	2.05	2.28
Mean	1.98	1.90	1.83		2.18	2.25	2.04	
P (0.05)	NS							
SEm ±	0.070							
Stage of Host introduction	240 Days after planting				240 Days after planting			
At the time of planting sandal	1.82	1.92	1.72	1.82	2.37	2.25	2.04	2.22
3 months after planting sandal	1.94	1.99	2.05	1.99	1.99	2.29	2.17	2.15
6 months after planting sandal	2.38	1.97	1.92	2.09	2.51	2.51	2.11	2.38
Mean	2.04	1.96	1.90		2.29	2.35	2.11	
P (0.05)	NS							
SEm ±	0.073							

Contd.

Table 6. Continued

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	270 Days after planting				270 Days after planting			
At the time of planting sandal	1.88	2.02	1.80	1.90	2.57	2.37	2.13	2.36
3 months after planting sandal	2.02	2.04	2.12	2.06	2.07	2.39	2.24	2.23
6 months after planting sandal	2.45	2.01	2.00	2.15	2.58	2.63	2.19	2.47
Mean	2.12	2.02	1.97		2.40	2.46	2.19	
P (0.05)	NS							
SEm ±	0.076							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	1.94	2.09	1.88	1.97	2.67	2.50	2.21	2.46
3 months after planting sandal	2.10	2.09	2.18	2.12	2.14	2.48	2.31	2.31
6 months after planting sandal	2.51	2.06	2.09	2.22	2.68	2.78	2.28	2.58
Mean	2.18	2.08	2.05		2.50	2.59	2.27	
P (0.05)	NS							
SEm ±	0.078							

Table 7. Number of leaves of sandal seedlings as affected by stage of host introduction and different levels of water stress

Provenances	Days after planting																			
	30		60		90		120		150		180		210		240		270		300	
	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M
Time of host introduction																				
At the time of planting sandal	11^{d}	12^{ab}	13	15	17^{c}	18^{ab}	19	20	20	22	20^{cd}	23^{b}	19^{bc}	20^{b}	21^{bc}	20^{bc}	22^{b}	21^{bc}	21^{c}	21^{c}
3 months after planting sandal	12^{cd}	13^{a}	14	16	18^{c}	19^{a}	19	20	20	21	19^{d}	22^{c}	18^{c}	19^{b}	19^{c}	20^{bc}	17^{d}	19^{cd}	13^{d}	15^{d}
6 months after planting sandal	12^{bc}	13^{a}	14	16	19^{bc}	19^{a}	20	20	20	23	21^{c}	25^{a}	20^{b}	25^{a}	21^{b}	28^{a}	23^{b}	30^{a}	24^{b}	33^{a}
P	0.027		NS		0.028		NS		NS		0.00		0.00		0.00		0.00		0.00	
Irrigation																				
Daily	11	13	14	15	16	18	18	20	19	22	21^{b}	24^{a}	20^{b}	22^{a}	22^{a}	24^{a}	23^{a}	24^{a}	24^{a}	24^{a}
Once in three days	12	13	14	16	16	19	18	21	20	22	20^{bc}	22^{a}	18^{c}	21^{ab}	19^{b}	22^{a}	19^{b}	23^{a}	17^{c}	22^{a}
Once in six days	12	13	14	16	17	18	18	20	19	22	19^{c}	22^{a}	18^{c}	22^{ab}	20^{b}	22^{a}	20^{b}	23^{a}	18^{bc}	22^{ab}
P	NS		NS		NS		NS		NS		0.0005		0.003		0.00		0.009		0.00	
Provenance Mean	12	13	14	16	16	18	18	20	20	20	20	23	19	22	20	23	20	23	20	23
P	NS		NS		NS		NS		NS		NS		NS		0.04		NS		NS	
SEm ±	0.55		0.593		0.77		0.817		0.878		0.923		0.824		1.083		1.552		2.167	

S – Shimoga provenance

M – Marayoor provenance

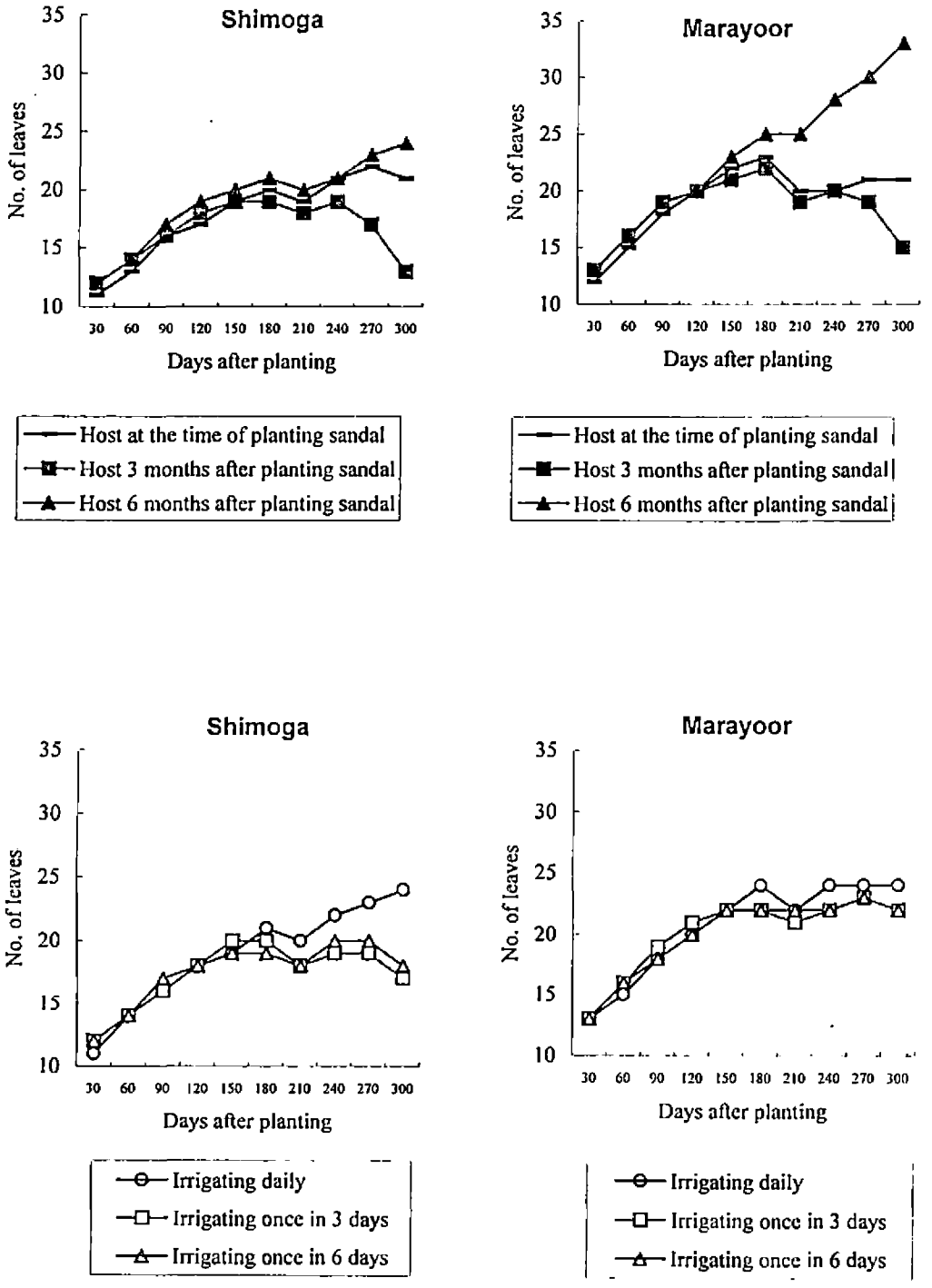


Fig. 4. Number of leaves of sandal seedlings in Shimoga and Marayoor provenance as affected by stage of host introduction and levels of water stress

Table 8. Interaction effects of stage of host introduction and irrigation levels on the number of leaves of sandal seedlings

Stage of host introduction	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
	30 Days after planting				60 Days after planting			
At the time of planting sandal	12	12	13	12	14	15	14	14
3 months after planting sandal	12	12	13	12	14	15	15	15
6 months after planting sandal	13	13	12	13	15	15	15	15
Mean	12	12	13		14	15	15	
P (0.05)	NS				NS			
SEm ±	0.55				0.59			
Stage of Host introduction	90 Days after planting				120 Days after planting			
At the time of planting sandal	16	17	17	17	18	19	18	18
3 months after planting sandal	17	17	18	17	18	19	20	19
6 months after planting sandal	18	18	18	18	20	20	19	20
Mean	17	17	18		18	19	19	
P (0.05)	NS				NS			
SEm ±	0.770				0.817			
Stage of Host introduction	150 Days after planting				180 Days after planting			
At the time of planting sandal	20	21	20	20	22	23	20	22
3 months after planting sandal	20	20	20	20	21	21	18	20
6 months after planting sandal	22	21	21	21	24	23	22	23
Mean	21	21	20		22	23	20	
P (0.05)	NS				NS			
SEm ±	0.878				0.923			
Stage of Host introduction	210 Days after planting				240 Days after planting			
At the time of planting sandal	20^{cd}	20^{cd}	19^{cd}	20	22^{b}	20^{c}	19^{c}	20
3 months after planting sandal	19^{cd}	19^{cd}	18^{d}	19	20^{c}	19^{c}	19^{c}	19
6 months after planting sandal	25^{a}	20^{bc}	22^{b}	22	27^{a}	22^{b}	24^{b}	24
Mean	22	20	20		23	20	21	
P (0.05)	0.009				0.04			
SEm ±	0.824				1.08			
Stage of Host introduction	270 Days after planting				300 Days after planting			
At the time of planting sandal	24^{b}	20^{c}	20^{cd}	21	25	18	18	20
3 months after planting sandal	17^{cd}	17^{d}	19^{cd}	18	14	14	14	14
6 months after planting sandal	30^{a}	25^{b}	25^{b}	26	33	26	26	28
Mean	24	20	21		24	19	19	
P (0.05)	0.02				NS			
SEm ±	1.55				2.17			

Table 9. Interaction effects of provenances, hosts and irrigation levels on number of leaves of sandal seedlings.

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	30 Days after planting				30 Days after planting			
At the time of planting sandal	11	11	11	11	12	13	13	13
3 months after planting sandal	11	11	12	11	13	13	13	13
6 months after planting sandal	12	12	12	12	14	13	13	13
Mean	11	11	12		13	13	13	
P (0.05)	NS							
SEm ±	0.318							
Stage of Host introduction	60 Days after planting				60 Days after planting			
At the time of planting sandal	13	14	13	13	15	15	15	15
3 months after planting sandal	14	13	14	14	15	16	16	16
6 months after planting sandal	14	14	14	14	15	16	16	16
Mean	14	14	14		15	16	16	
	NS							
SEm ±	0.343							
Stage of Host introduction	90 Days after planting				90 Days after planting			
At the time of planting sandal	15	16	16	16	18	18	17	18
3 months after planting sandal	16	16	16	16	18	19	20	19
6 months after planting sandal	17	17	17	17	18	19	18	18
Mean	16	16	16		18	19	18	
P (0.05)	NS							
SEm ±	0.444							
Stage of Host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	17	17	18	17	19	20	19	19
3 months after planting sandal	17	17	18	17	19	20	21	20
6 months after planting sandal	18	18	19	18	21	21	20	21
Mean	17	17	18		20	20	20	
P (0.05)	NS							
SEm ±	0.471							

Contd.

Table 9. Continued

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	150 Days after planting				150 Days after planting			
At the time of planting sandal	18	20	19	19	22	22	22	22
3 months after planting sandal	19	19	19	19	21	22	21	21
6 months after planting sandal	20	20	20	20	23	23	22	23
Mean	19	20	19		22	22	22	
P (0.05)	NS							
SEm ±	0.507							
Stage of Host introduction	180 Days after planting				180 Days after planting			
At the time of planting sandal	20	21	19	20	24	24	22	23
3 months after planting sandal	20	19	18	19	22	24	18	21
6 months after planting sandal	23	19	20	21	25	26	24	25
Mean	21	20	19		23	24	21	
P (0.05)	NS							
SEm ±	0.533							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	20	19	18	18	19	20	20	20
3 months after planting sandal	19	17	16	17	19	20	19	19
6 months after planting sandal	22	17	19	20	27	23	25	25
Mean	20	17	17		22	21	21	
P (0.05)	NS							
SEm ±	0.476							
Stage of Host introduction	240 Days after planting				240 Days after planting			
At the time of planting sandal	23	19	20	21	22	20	18	20
3 months after planting sandal	19	19	19	19	20	19	20	20
6 months after planting sandal	24	19	20	21	29	26	27	27
Mean	22	19	20		24	21	21	
P (0.05)	NS							
SEm ±	0.625							

Contd.

Table 9. Continued

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	270 Days after planting				270 Days after planting			
At the time of planting sandal	24	20	21	22	24	21	19	21
3 months after planting sandal	17	15	18	17	17	17	20	18
6 months after planting sandal	28	21	19	22	32	32	31	31
Mean	24	19	19		24	24	23	
P (0.05)	NS							
SEm ±	0.896							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	26	17	19	21	25	19	17	20
3 months after planting sandal	14	12	14	13	14	15	15	15
6 months after planting sandal	32	20	21	24	34	32	32	32
Mean	24	16	18		24	22	21	
P (0.05)	NS							
SEm ±	1.251							

Interactionsof sandal provenances, hosts and irrigation levels on the number of leaves of sandal seedlings was not significant in any of the stages from 30 to 300 DAP (Table 9). However, the host introduced at the time of planting sandal and irrigated once in three days had less number of leaves as compared to seedlings watered daily.

4.1.4 Leaf Area

The leaf area of sandal seedlings at 120, 210 and 300 DAP are shown in Table 10, 11 and 12 and Fig. 5. The introduction of host showed significant influence on the leaf area of sandal seedlings only at 300 DAP. In both the provenances, the leaf area increased when the hosts were introduced with host six months after planting sandal. The leaf area of the sandal seedlings was least in both the provenances when the host was introduced at the time of planting sandal. Soil moisture stress significantly influenced the leaf area only during early phase (120 DAP). During the later phase the influence of water stress were not significant. The leaf area of the seedlings of Marayoor provenance increased, when they were water stressed for three and six days whereas the leaf area in the seedlings of Shimoga provenance decreased with increase in water stress (Table 10).

The interaction effects of stage of host introduction and irrigation levels on the leaf area of sandal seedlings was significant at 120 and 300 DAP (Table 11). At 120 DAP the seedlings watered once in six days and host introduced three months after planting sandal recorded a higher leaf area. At 300 DAP all the seedlings where the host was introduced six months after planting sandal had higher leaf area.

Interaction of sandal provenances, hosts and irrigation levels on the leaf area of sandal seedlings were not significant at any of the stages. However, at 120 and 300 DAP the introduction of host at the time of planting sandal and watered once in three and six days had lowest leaf area, but were not significantly different (Table 12).

4.1.5 Root length

The root length of sandal seedlings at 120, 210 and 300 DAP are shown in Table 13, 14 and 15 and Fig. 6. At 120 DAP the root length decreased with the

Table 10. Leaf area (cm^2) of sandal seedlings as affected by stage of host introduction and different levels of water stress

Provenances	Days after planting					
	120		210		300	
	Shimoga	Marayoor	Shimoga	Marayoor	Shimoga	Marayoor
Time of host introduction						
At the time of planting sandal	43.75	71.44	78.90	75.35	125.4^{c}	126.5^{c}
3 months after planting sandal	64.48	70.75	68.25	93.96	135.1^{bc}	148.1^{ab}
6 months after planting sandal	57.91	68.03	62.81	70.31	154.3^{a}	156.3^{a}
P	NS		NS		0.00	
Irrigation						
Daily	56.92^{bc}	54.36^{bc}	67.56	82.87	134.51	143.5
Once in three days	61.51^{b}	78.91^{a}	66.56	75.86	141.90	134.6
Once in six days	47.70^{c}	76.95^{a}	75.84	80.88	138.40	152.8
P	0.005		NS		NS	
Provenance Mean	55.37	70.07	69.98	79.87	138.3	143.6
P	NS		NS		NS	
SEm ±	7.25		18.35		8.72	

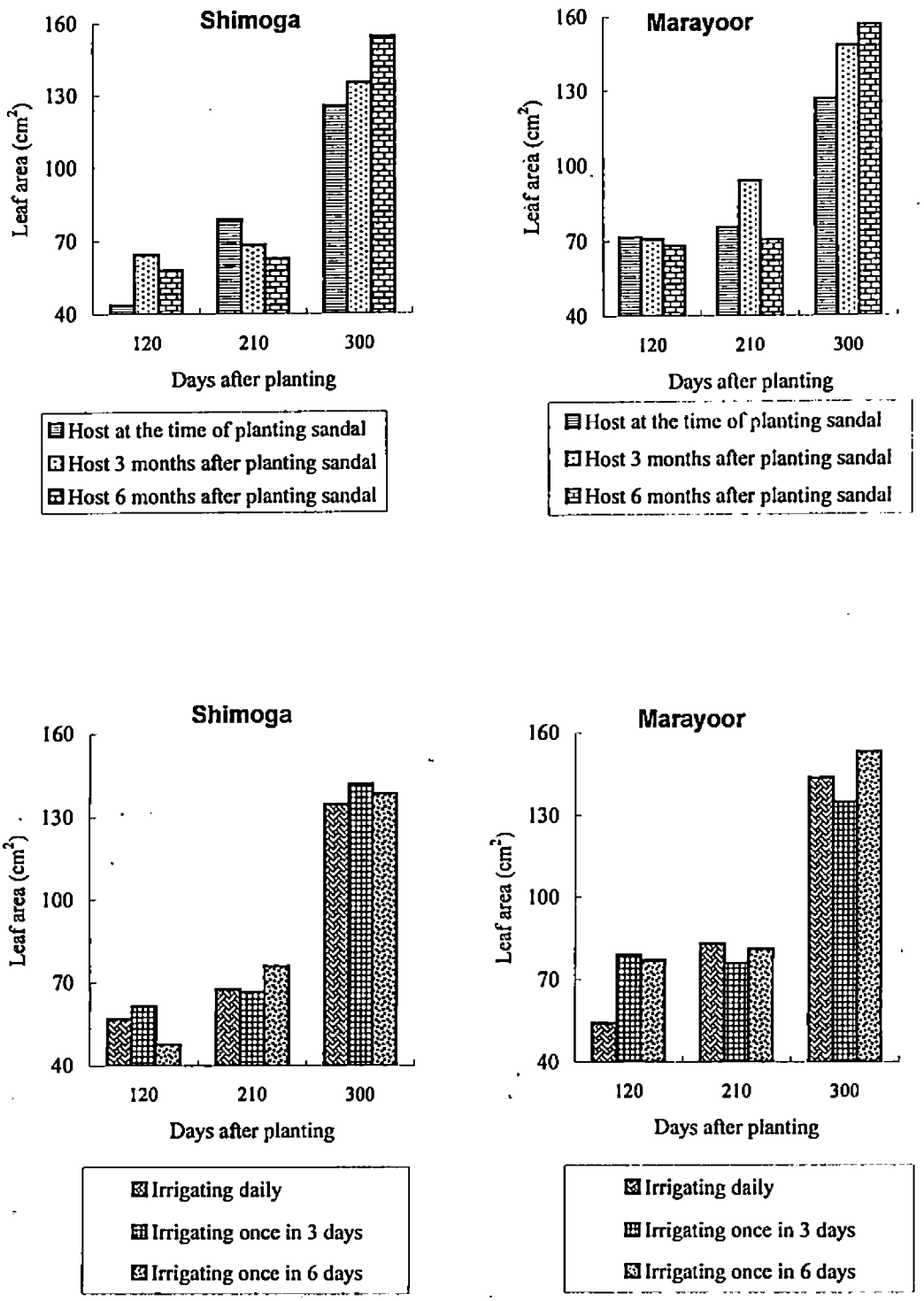


Fig. 5. Leaf area of sandal seedlings in Shimoga and Marayoor provenance as affected by stage of host introduction and levels of water stress

Table 11. Interaction effects of stage of host introduction and irrigation levels on leaf area (cm^2) of sandal seedlings.

Stage of host introduction	Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean
	120 Days after planting			
At the time of planting sandal	55.19^{bc}	63.22^{abc}	54.38^{bc}	57.60
3 months after planting sandal	48.72^{c}	77.25^{a}	76.87^{a}	67.61
6 months after planting sandal	63.02^{abc}	70.17^{ab}	55.71^{bc}	62.97
Mean	55.64	70.21	62.32	
P (0.05)	0.01			
SEm ±	7.25			
Stage of Host introduction	210 Days after planting			
At the time of planting sandal	97.70	63.24	70.43	77.12
3 months after planting sandal	66.09	74.41	102.0	80.83
6 months after planting sandal	61.05	75.98	62.64	66.56
Mean	74.95	71.21	78.36	
P (0.05)	NS			
SEm ±	18.35			
Stage of Host introduction	300 Days after planting			
At the time of planting sandal	135.60^{bcd}	126.10^{de}	116.30^{e}	126.00
3 months after planting sandal	133.4^{cde}	137.3^{bcd}	154.1^{ab}	142.33
6 months after planting sandal	148.0^{abc}	151.4^{abc}	166.5^{a}	151.17
Mean	135.60	138.27	145.63	
P (0.05)	0.01			
SEm ±	8.72			

Table 12. Interaction effects of provenances, hosts and irrigation levels on leaf area (cm^2) of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	44.35	48.55	38.34	43.75	66.02	77.88	70.43	71.44
3 months after planting sandal	60.67	70.16	62.61	64.48	36.76	84.35	91.13	70.75
6 months after planting sandal	65.74	65.83	42.15	57.91	60.30	74.50	69.28	68.03
Mean	56.92	61.51	47.70		54.36	78.91	76.95	
P (0.05)	NS							
SEm ±	4.185							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	104.8	66.82	65.04	78.89	90.55	59.66	75.83	75.35
3 months after planting sandal	43.63	55.30	105.80	68.24	90.16	93.53	98.18	93.96
6 months after planting sandal	54.22	77.57	56.64	62.81	67.89	74.40	68.63	70.31
Mean	67.55	66.56	75.83		82.87	75.86	80.88	
P (0.05)	NS							
SEm ±	10.592							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	129.9	140.9	105.4	125.4	141.2	111.2	127.2	126.53
3 months after planting sandal	121.9	134.2	149.0	135.03	145.0	140.3	159.1	148.13
6 months after planting sandal	151.7	150.5	160.8	154.33	144.4	152.4	172.1	156.30
Mean	134.50	14187	138.40		143.53	134.63	152.80	
P (0.05)	NS							
SEm ±	5.036							

Table 13. Root length (cm) of sandal seedlings as affected by stage of host introduction and different levels of water stress.

Provenances	Days after planting					
	120 DAP		210 DAP		300 DAP	
	Shimoga	Marayoor	Shimoga	Marayoor	Shimoga	Marayoor
Time of host introduction						
At the time of planting sandal	13.64^{c}	14.82^{bc}	19.59	19.34	21.38^{b}	22.21^{ab}
3 months after planting sandal	17.00^{a}	16.02^{ab}	18.50	20.21	22.69^{ab}	22.26^{ab}
6 months after planting sandal	16.19^{ab}	15.50^{ab}	18.39	19.60	23.04^{ab}	24.17^{a}
P	0.002		NS		0.044	
Irrigation						
Daily	11.92^{e}	12.32^{de}	16.43^{d}	16.66^{d}	19.50^{d}	19.69^{d}
Once in three days	14.00^{d}	16.10^{c}	18.61^{c}	19.59^{c}	22.98^{bc}	22.32^{c}
Once in six days	20.91^{a}	17.92^{b}	21.43^{b}	22.91^{a}	24.63^{ab}	26.63^{a}
P	0.00		0.00		0.00	
Provenance Mean	15.61	15.44	18.83	19.71	22.37	22.88
P	NS		NS		NS	
SEm ±	1.02		0.723		1.210	

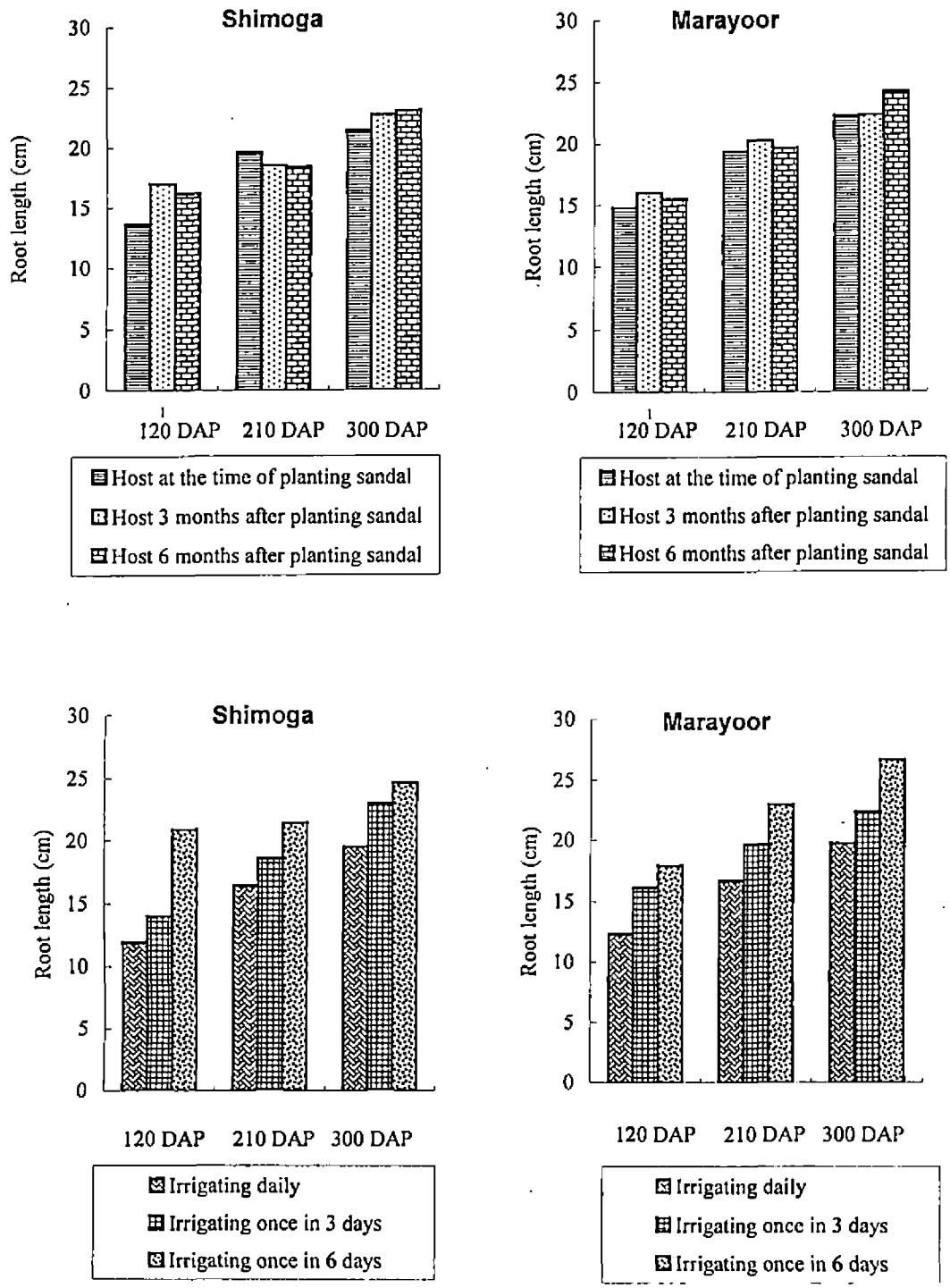


Fig. 6. Root length of sandal seedlings in Shimoga and Marayoor provenance as affected by stage of host introduction and levels of water stress

Table 14. Interaction effects of stage of host introduction and irrigation levels on root length (cm) of sandal seedlings

Stage of host introduction	Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean
	120 Days after planting			
At the time of planting sandal	12.10^{c}	14.30^{cd}	16.30^{c}	14.23
3 months after planting sandal	12.40^{dc}	14.93^{c}	22.20^{a}	16.51
6 months after planting sandal	11.87^{e}	15.92^{c}	19.75^{b}	15.85
Mean	12.12	15.05	19.42	
P (0.05)	0.00			
SEm ±	1.02			
Stage of Host introduction	210 Days after planting			
At the time of planting sandal	15.95^{d}	19.17^{c}	23.28^{a}	19.47
3 months after planting sandal	16.85^{d}	18.80^{c}	22.42^{a}	19.36
6 months after planting sandal	16.83^{d}	19.33^{c}	20.82^{b}	18.99
Mean	16.54	19.10	22.17	
P (0.05)	0.02			
SEm ±	0.722			
Stage of Host introduction	300 Days after planting			
At the time of planting sandal	19.44	20.76	25.20	21.80
3 months after planting sandal	18.62	23.00	25.80	22.47
6 months after planting sandal	20.73	24.19	25.89	23.60
Mean	19.60	22.65	25.63	
P (0.05)	NS			
SEm ±	1.21			

Table 15. Interaction effects of provenances, hosts and irrigation levels on root length (cm) of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	11.90^{h}	13.27^{fgh}	15.77^{cdef}	13.65	12.30^{gh}	15.33^{defg}	16.83^{cde}	14.82
3 months after planting sandal	11.67^{h}	14.00^{efgh}	23.33^{a}	16.33	13.13^{fgh}	15.87^{cdef}	19.07^{bc}	16.02
6 months after planting sandal	12.20^{gh}	14.73^{defgh}	21.63^{b}	16.19	11.53^{h}	17.10^{cde}	17.87^{cd}	15.50
Mean	11.92	14.00	20.22		12.32	16.10	17.92	
P (0.05)	0.05							
SEm ±	0.056							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	15.87	19.23	23.67	19.59	16.03	19.10	22.90	19.34
3 months after planting sandal	16.20	18.07	21.23	18.50	17.50	19.53	23.60	20.21
6 months after planting sandal	17.23	18.53	19.40	18.39	16.43	20.13	22.23	19.59
Mean	16.43	18.61	21.43		16.65	19.58	22.91	
P (0.05)	NS							
SEm ±	0.417							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	19.31	21.31	23.53	21.38	19.57	20.20	26.87	22.21
3 months after planting sandal	18.93	23.71	25.43	22.69	18.30	22.30	26.17	22.26
6 months after planting sandal	20.25	23.92	24.93	23.03	21.20	24.47	26.85	24.17
Mean	19.50	22.98	24.63		19.69	22.32	26.63	
P (0.05)	NS							
SEm ±	0.699							

introduction of host in both the provenances. Sandal seedlings with host plant at the time of planting resulted in shorter roots as compared to introduction of host at three or six months after planting sandal. There was no significant difference between the root length of sandal seedlings when the host was introduced three or six months after planting sandal in both the provenances. This response was more prominent in Shimoga provenance. At 210 DAP there was no significant increase in the root length of sandal seedlings due to the difference in date of host introduction. At 300 DAP the seedlings where the host was introduced six months after planting sandal had the longest root. Water stress resulted in a significant increase of root length at 120 DAP. As the levels of stress increased, there was an increase in the root length of the sandal seedlings and was more prominent in Shimoga provenance (Table 13)

The interaction effects of stage of host introduction and irrigation levels on the root length of sandal seedlings was significant only at 120 and 210 DAP (Table 14). As the levels of water stress increased there was a increase in the root length irrespective of stage of host introduction.

Interaction of sandal provenances, hosts and irrigation levels on the root length of sandal seedlings was significant only at 120 DAP (Table 15). The seedlings watered once in six days and where the host was introduced at the time of planting sandal had lowest root length in both the provenances. In seedlings that were irrigated daily, such a difference was not significant. At 210 and 300 DAP the same pattern of results were not obtained.

4.1.6 Shoot dry weight

The shoot dry weight of sandal seedlings at 120, 210 and 300 DAP are shown in Table 16. Significant variations were observed only at 210 DAP. The shoot dry weight of seedlings of Shimoga provenance where the host was introduced at the time of planting sandal and six months after planting sandal had highest shoot dry weight. The influence of water stress on shoot dry weight of sandal seedlings was significant only at 210 and 300 DAP. As the level of water stress increased, there was a decrease in

Table 16. Shoot dry weight (g) of sandal seedlings as affected by stage of host introduction and levels of water stress

Provenances	Days after planting					
	120 DAP		210 DAP		300 DAP	
	Shimoga	Marayoor	Shimoga	Marayoor	Shimoga	Marayoor
Time of host introduction						
At the time of planting sandal	0.71	0.68	2.30^{a}	2.12^{ab}	3.12	2.98
3 months after planting sandal	0.61	0.67	2.00^{bc}	1.78^{c}	2.98	2.86
6 months after planting sandal	0.67	0.58	2.33^{a}	2.00^{bc}	3.42	3.48
P	NS		0.002		NS	
Irrigation						
Daily	0.70	0.69	2.72^{a}	2.38^{b}	4.62^{a}	3.91^{a}
Once in three days	0.68	0.63	2.28^{b}	1.98^{c}	2.44^{b}	2.47^{b}
Once in six days	0.62	0.60	1.62^{d}	1.54^{d}	2.46^{b}	2.95^{b}
P	NS		0.00		0.00	
Provenance Mean	0.67	0.64	2.21	1.97	3.17	3.11
P	0.234		NS		0.149	
SEm ±	0.065		0.153		0.486	

the shoot dry weight of sandal seedlings in both the provenances. Severe water stress even killed the seedlings at some stages (Plate 5).

Interactions of sandal provenances, hosts and irrigation levels on the shoot dry weight of sandal seedlings were not significant at any of the stages.

4.1.7 Root dry weight

The root dry weight of sandal seedlings at 120, 210 and 300 DAP are shown in Table 17. The root dry weight of sandal seedlings did not show any significant difference by the introduction of host at various stages. Root dry weight showed significant variations due to the levels of water stress. At 120 DAP as the levels of water stress increased the seedlings of sandal showed a lower dry root weight, though not significant. A similar pattern of decrease in dry root weight with increase in water stress was observed at 210 and 300 DAP.

Interaction of sandal provenance, hosts and irrigation levels were not significantly different.

4.1.8 Total Dry matter

Total dry matter production of sandal seedlings at 120, 210 and 300 DAP are shown in Table 18, 19 and 20 and Fig. 7. Due to the introduction of host, the total dry matter production showed significant variation only during 210 DAP. At this stage the introduction of host at the time of planting sandal or six months after planting sandal had higher dry matter content as compared to the seedlings where the host was introduced three months after planting sandal. This was more prominent in Shimoga provenance. The level of water stress significantly influenced the total dry matter content of sandal seedlings. As the levels of water stress increased the dry matter content of the seedlings decreased. The dry weight of the seedlings of Shimoga provenance was high as compared to Marayoor provenance at 210 and 300 DAP (Table 18).

The interaction effects of stages of host introduction and irrigation levels on the total dry matter production of sandal seedlings was significant only at 120 and 210

Plate 5. Effect of severe water stress on sandal seedlings in presence of host.

Table. 17. Root dry weight (g) of sandal seedlings as affected by stage of host introduction and different levels of water stress

Provenances	Days after planting					
	120 DAP		210 DAP		300 DAP	
	Shimoga	Marayoor	Shimoga	Marayoor	Shimoga	Marayoor
Time of host introduction						
At the time of planting sandal	0.56	0.66	1.45	1.52	2.46	2.32
3 months after planting sandal	0.60	0.66	1.37	1.50	2.43	2.25
6 months after planting sandal	0.60	0.57	1.43	1.50	2.26	2.36
P	NS		NS		NS	
Irrigation						
Daily	0.56	0.65	1.64^{a}	1.58^{ab}	2.81^{a}	2.53^{ab}
Once in three days	0.61	0.67	1.37^{cd}	1.54^{abc}	2.27^{ab}	2.05^{b}
Once in six days	0.60	0.51	1.25^{d}	1.40^{bcd}	2.12^{b}	2.35^{ab}
P	NS		0.0003		0.045	
Provenance Mean	0.59	0.62	1.42	1.51	2.40	2.31
P	NS		NS		NS	
SEm ±	0.040		0.113		0.363	

Table 18. Total dry matter production (g) of sandal seedlings as affected by stage of host introduction and levels of water stress

Provenances	Days after planting					
	120 DAP		210 DAP		300 DAP	
	Shimoga	Marayoor	Shimoga	Marayoor	Shimoga	Marayoor
Time of host introduction						
At the time of planting sandal	1.28	1.34	3.75^{a}	3.64^{abc}	5.58	5.30
3 months after planting sandal	1.22	1.33	3.37^{bc}	3.28^{c}	5.45	5.11
6 months after planting sandal	1.27	1.16	3.77^{a}	3.50^{abc}	5.63	5.84
P	NS		0.003		NS	
Irrigation						
Daily	1.26^{ab}	1.35^{a}	4.37^{a}	3.96^{b}	7.42^{a}	6.43^{a}
Once in three days	1.29^{abc}	1.30^{ab}	3.65^{bc}	3.51^{c}	4.72^{b}	4.52^{b}
Once in six days	1.22^{ab}	1.18^{b}	2.87^{d}	2.94^{d}	4.57^{b}	5.30^{ab}
P	0.025		0.00		0.00	
Provenance Mean	1.25	1.28	3.63	3.47	5.56	5.42
P	0.021		NS		NS	
SEm ±	0.073		0.188		0.669	

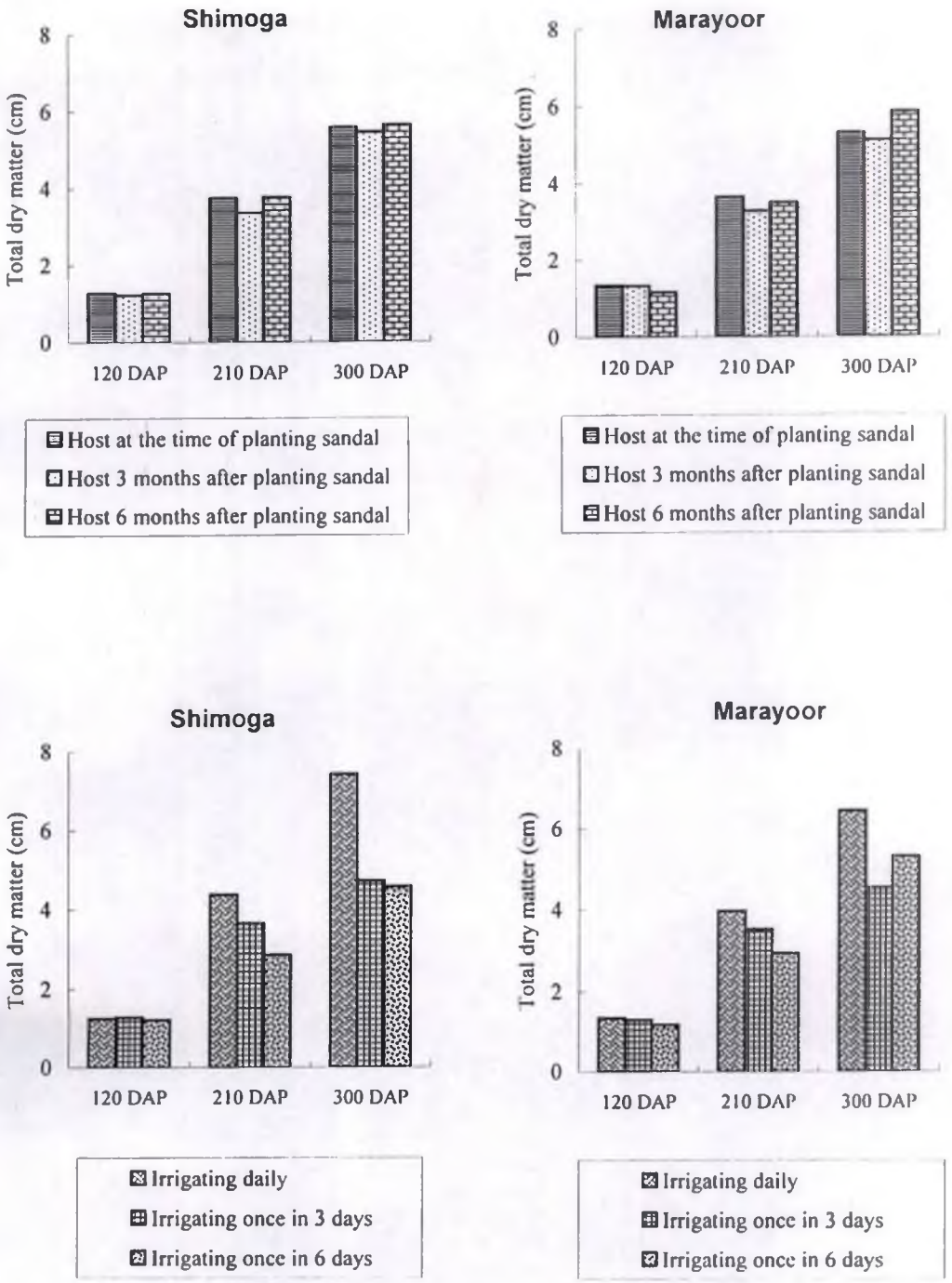


Fig. 7. Total dry matter production of sandal seedlings in Shimoga and Marayoor provenance as affected by stage of host introduction and levels of water stress

Table 19. Interaction effects of stage of host introduction and irrigation levels on total dry matter content (g) of sandal seedlings

Stage of host introduction	Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean
	120 Days after planting			
At the time of planting sandal	1.26^{ab}	1.35^{a}	1.32^{a}	1.31
3 months after planting sandal	1.40^{a}	1.27^{ab}	1.15^{b}	1.27
6 months after planting sandal	1.25^{ab}	1.28^{ab}	1.12^{b}	1.22
Mean	1.30	1.30	1.20	
P (0.05)	0.04			
SEm ±	0.07			
Stage of Host introduction	210 Days after planting			
At the time of planting sandal	4.08^{a}	4.04^{a}	2.97^{cd}	3.70
3 months after planting sandal	4.06^{a}	3.21^{bc}	2.69^{d}	3.32
6 months after planting sandal	4.35^{a}	3.50^{b}	3.05^{cd}	3.63
Mean	4.16	3.58	2.90	
P (0.05)	0.02			
SEm ±	0.09			
Stage of Host introduction	300 Days after planting			
At the time of planting sandal	7.14	4.40	4.78	5.44
3 months after planting sandal	6.52	4.67	4.65	5.28
6 months after planting sandal	7.13	4.78	5.38	5.76
Mean	6.93	4.62	4.94	
P (0.05)	NS			
SEm ±	0.669			

Table 20. Interaction effects of provenances, hosts and irrigation levels on total dry matter (g) of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	1.27^{bcd}	1.21^{cd}	1.34^{abcd}	1.27	1.25^{bcd}	1.48^{ab}	1.30^{bcd}	1.34
3 months after planting sandal	1.26^{bcd}	1.23^{bcd}	1.16^{d}	1.21	1.55^{a}	1.30^{bcd}	1.13^{d}	1.33
6 months after planting sandal	1.25^{bcd}	1.42^{abc}	1.14^{d}	1.27	1.25^{bcd}	1.13^{d}	1.10^{d}	1.16
Mean	1.26	1.29	1.21		1.35	1.30	1.18	
P (0.05)	0.02							
SEm ±	0.042							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	4.22	4.04	2.99	3.75	3.94	4.03	2.94	3.64
3 months after planting sandal	4.27	3.33	2.51	3.37	3.86	3.10	2.87	3.28
6 months after planting sandal	4.62	3.59	3.10	3.77	4.08	3.42	3.00	3.50
Mean	4.37	3.65	2.87		3.96	3.52	2.94	
P (0.05)	NS							
SEm ±	0.109							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	7.40	4.95	4.38	5.58	6.87	3.85	5.17	5.30
3 months after planting sandal	7.23	5.05	4.08	5.45	5.81	4.30	5.22	5.11
6 months after planting sandal	7.64	4.15	5.26	5.68	6.62	5.42	5.50	5.85
Mean	7.42	4.72	4.57		5.43	4.52	5.30	
P (0.05)	NS							
SEm ±	0.386							

DAP (Table 19). At 120 DAP, host introduced three months after planting sandal and watered daily had higher total dry matter content. At 210 DAP all the seedlings watered daily had higher total dry matter content irrespective of stage of host introduction.

Interaction of sandal provenances, host and irrigation levels on total dry matter production of sandal seedlings were significant only at 120 DAP (Table 20). The total dry matter production of Shimoga provenance was higher when the host was introduced at the time of planting sandal and irrigated once in six days. But this was on par with seedlings irrigated once in three days or irrigated daily. Introduction of host after three or six months after planting sandal and irrigated once in six days resulted in considerable decrease in total dry matter production in Shimoga provenance. More or less a similar pattern was observed in Marayoor provenance. Maximum dry matter production was observed when the host was introduced at the time of planting sandal and irrigated once in three days.

4.1.9 Haustorial connections

The number of haustorial connections between sandal and host (red gram) are shown in Table 21 and Fig. 8. Haustorial connections were found only at 300 DAP (Plate 3 and 4). However, the number of haustorial connections were not significantly different in both the provenances. The stage of host introduction or the levels of water stress also did not show any significant effect on the haustorial connections between sandal and the host plants in both the provenances.

4.2 PHYSIOLOGICAL PARAMETERS OF SANDAL

4.2.1 Pre-dawn water potential

The pre-dawn water potential of sandal seedlings at 120, 210 and 300 DAP are shown in Table 22, 23 and 24 and Fig. 9. Significant variation in pre-dawn water potential was observed between provenances and due to the difference in date of introduction of host. At all the stages of observation (120, 210 and 300 DAP) the seedlings of Marayoor provenance recorded lower pre-dawn water potential as compared to Shimoga provenance. However, the influence of time of host introduction

Table 21. Number of haustorial connections between the sandal and the host at 300 DAP as affected by stage of host introduction and different levels of water stress.

Provenances	Shimoga	Marayoor
	Days after planting	Days after planting
Stage of Host introduction		
At the time of planting sandal	0.8	1.1
3 months after planting sandal	1.2	1.4
6 months after planting sandal	1.0	1.0
P	NS	
Irrigation		
Daily	1.1	1.1
Irrigating once in three days	1.0	1.3
Irrigating once in six days	0.9	1.1
P	NS	
Provenance Mean	1.00	1.2
P	NS	
SEm ±	0.53	

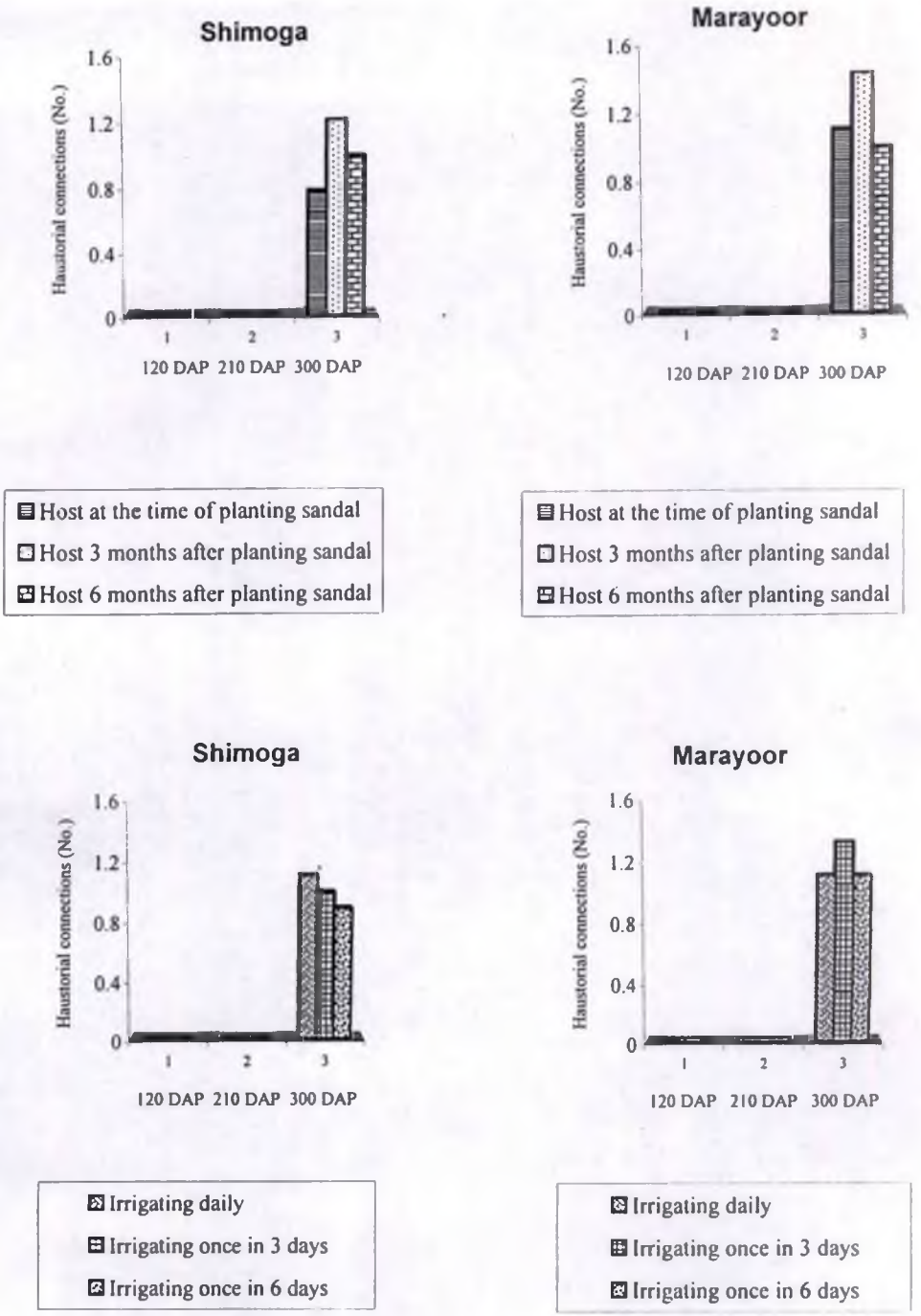


Fig. 8. Haustorial connections between sandal and host seedlings as affected by stage of host introduction and levels of water stress in Shimoga and Marayoor provenance

Plate 3. Haustorial connection between sandal seedlings of Shimoga provenance and red gram seedlings at 300 days after planting

Plate 4. Haustorial connection between sandal seedlings of Marayoor provenance and red gram seedlings at 300 days after planting.

Table 22. Pre-dawn water potential (MPa) of sandal seedlings as affected by stage of host introduction and different levels of water stress

Provenances	Days after planting					
	120		210		300	
	Shimoga	Marayoor	Shimoga	Marayoor	Shimoga	Marayoor
Time of host introduction						
At the time of planting sandal	-1.46	-1.73	-2.38^{c}	-2.52^{b}	-2.11	-2.31
3 months after planting sandal	-1.56	-1.73	-2.38^{c}	-2.54^{b}	-2.12	-2.27
6 months after planting sandal	-1.50	-1.77	-2.47^{bc}	-2.67^{a}	-1.93	-2.39
P	NS		0.002		NS	
Irrigation						
Daily	-1.32^{c}	-1.85^{a}	-2.18^{e}	-2.44^{c}	-1.90^{c}	-2.18^{b}
Once in three days	-1.59^{b}	-1.80^{a}	-2.30^{d}	-2.56^{b}	-2.07^{b}	-2.38^{a}
Once in six days	-1.60^{b}	-1.58^{b}	-2.75^{a}	-2.73^{a}	-2.19^{b}	-2.41^{a}
P	0.0001		0.00		0.00	
Provenance Mean	-1.51	-1.74	-2.41	-2.58	-2.05	-2.32
P	NS		0.0002		0.007	
SEm ±	0.437		0.591		0.716	

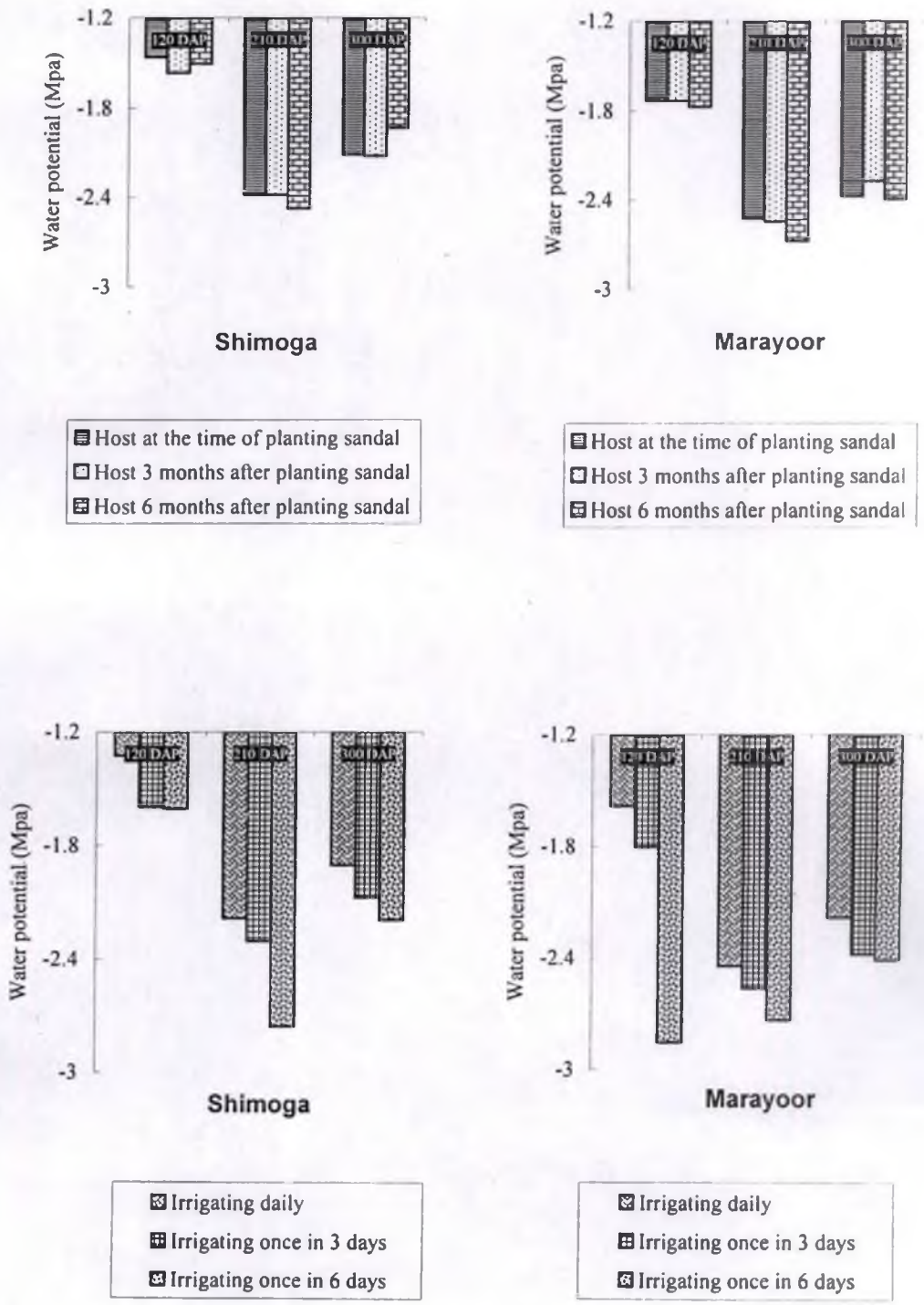


Fig. 9. Water potential of sandal seedlings in Shimoga and Marayoor provenance as affected by stage of host introduction and levels of water stress

Table 23. Interaction effects of stage of host introduction and irrigation levels on water potential (MPa) of sandal seedlings

Stage of host introduction	Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean
	120 Days after planting			
At the time of planting sandal	-1.15a	-1.18a	-0.86^{b}	-1.06
3 months after planting sandal	-1.06^{a}	-0.9^{b}	-0.53^{c}	-0.83
6 months after planting sandal	-0.79^{b}	-0.52^{c}	-1.12^{a}	-0.81
Mean	1.00	-0.87	-0.84	
P (0.05)	0.00			
SEm ±	0.57			
Stage of Host introduction	210 Days after planting			
At the time of planting sandal	-1.20^{b}	-1.17^{b}	-1.14^{b}	-1.17
3 months after planting sandal	-1.42^{a}	-0.78^{cd}	-1.05^{b}	-1.08
6 months after planting sandal	-1.12^{b}	-0.87^{c}	-0.63^{d}	8.97
Mean	-1.27	-0.94	-0.94	
P (0.05)	0.00			
SEm ±	0.920			
Stage of Host introduction	300 Days after planting			
At the time of planting sandal	-1.20^{b}	-1.00^{c}	-0.99^{c}	-1.07
3 months after planting sandal	-1.34^{a}	-0.86^{d}	-0.87^{d}	-1.02
6 months after planting sandal	-1.22^{ab}	-1.01^{c}	-0.79^{d}	-1.01
Mean	-1.25	-0.96	-0.88	
P (0.05)	0.00			
SEm ±	0.615			

Table 24. Interaction effects of provenances, hosts and irrigation levels on water potential (MPa) of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	-1.22	-1.48	-1.70	-1.46	-1.85	-1.68	-1.67	-1.73
3 months after planting sandal	-1.42	-1.72	-1.54	-1.56	-1.83	-1.83	-1.54	-1.73
6 months after planting sandal	-1.34	-1.59	-1.58	-1.50	-1.89	-1.89	-1.55	-1.78
Mean	-1.33	-1.60	-1.61		-1.86	-1.8	1.59	
P (0.05)	NS							
SEm ±	0.252							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	-2.17^{i}	-2.39^{gh}	-2.59^{cdef}	-2.38	-2.47^{efgh}	-2.46^{efgh}	-2.65^{bcde}	-2.53
3 months after planting sandal	-2.10^{i}	-2.40^{fgh}	-2.64^{bcde}	-2.38	-2.35^{gh}	-2.53^{defg}	-2.75^{bc}	-2.54
6 months after planting sandal	-2.28^{hi}	-2.11^{i}	-3.03^{a}	-2.47	-2.53^{defgh}	-2.68^{bcd}	-2.81^{b}	-2.67
Mean	-2.18	-2.30	2.75		-2.45	-2.56	-2.73	
P (0.05)	0.00							
SEm ±	0.341							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	-2.02^{d}	-2.15^{cd}	-2.18^{bcd}	-2.12	-2.18^{bcd}	-2.32^{abc}	-2.43^{a}	-2.31
3 months after planting sandal	-2.07^{d}	-2.07^{d}	-2.23^{abcd}	-2.12	-2.04^{d}	-2.43^{a}	-2.36^{abc}	-2.28
6 months after planting sandal	-1.62^{e}	-2.00^{d}	-2.18^{bcd}	-1.93	-2.33^{abc}	-2.40^{ab}	-2.46^{a}	-2.40
Mean	-1.90	-2.07	-2.20		-2.18	-2.38	-2.42	
P (0.05)	0.01							
SEm ±	0.413							

was significant only during 210 DAP. Introducing host at the time of planting sandal or three months after planting sandal in Marayoor provenance, resulted in higher water potential as compared to introduction of host six months after planting sandal. The influence of water stress on the water potential of sandal seedlings had a significant effect at all the stages. In general water stressed plants showed lower water potential at all the stages except in Marayoor provenance at 120 DAP (Table 22).

The interaction effects of stage of host introduction and irrigation levels on the water potential of sandal seedlings was significant only at 120 and 210 DAP (Table 23). At 120 DAP the plants watered once in six days recorded lowest water potential. The plants watered once in six days and host introduced six months after planting sandal recorded lowest water potential at 210 DAP.

Interaction of sandal provenances, stage of host introduction and levels of water stress on pre-dawn water potential was highly significant at 210 and 300 DAP (Table 24). At 210 DAP the lowest water potential was observed when the sandal seedlings of Shimoga provenance were water stressed for six days and the host introduced after six months of planting sandal. At 300 DAP the water potential was less in seedlings watered once in six days and host introduced six months after planting sandal, in Shimoga provenance and the seedlings where the host was introduced six months after planting sandal and watered once in six days in the case of Marayoor provenance. The water potential at 120 DAP in general were higher as compared to those recorded at 210 and 300 DAP.

4.2.2 Leaf diffusive resistance

Leaf diffusive resistance of sandal seedlings recorded at 120, 210 and 300 DAP (at the end of water stress cycle) is shown in Table 25, 26, 27 and 28 and Fig. 10. The introduction of host, at any of the stages of sandal growth did not show significant differences in the leaf diffusive resistance of sandal seedlings at both 0800 H and 1400 H in both the provenances. The leaf diffusive resistance increased as the level of water stress increased and was significantly different at 120 and 210 DAP. At this stage, the

Table 25. Leaf diffusive resistance (s cm^{-1}) of sandal seedlings as affected by stage of host of introduction and different levels of water stress

Provenances	Days after planting											
	120 DAP				210 DAP				300 DAP			
	S	M	S	M	S	M	S	M	S	M	S	M
	0800 Hrs	0800 Hrs	1400 Hrs	1400 Hrs	0800 Hrs	0800 Hrs	1400 Hrs	1400 Hrs	0800 Hrs	0800 Hrs	1400 Hrs	1400 Hrs
Time of host introduction												
At the time of planting sandal	19.94 (20.06)	3.00 (133.33)	6.73 (59.44)	7.26 (55.10)	16.41 (24.38)	15.46 (25.87)	6.83 (58.57)	8.08 (49.50)	0.95 (421.05)	1.10 (363.64)	3.19 (125.39)	6.55 (61.07)
3 months after planting sandal	10.80 (37.04)	5.90 (67.80)	5.22 (76.62)	8.23 (48.60)	3.89 (102.83)	17.38 (23.01)	9.30 (43.01)	7.48 (53.48)	0.72 (555.55)	0.81 (493.83)	3.38 (118.34)	3.53 (113.31)
6 months after planting sandal	17.08 (23.42)	3.92 (102.04)	5.44 (73.53)	8.05 (49.69)	15.40 (25.97)	10.64 (37.59)	6.18 (64.72)	6.11 (65.47)	1.14 (350.87)	1.45 (275.86)	3.82 (104.71)	4.9 (81.14)
P	NS		NS		NS		NS		NS		NS	
Irrigation												
Daily	5.63 (71.05)	3.10 (129.03)	4.51^{c} (88.69)	3.45^{c} (115.94)	9.57^{b} (41.80)	3.48^{b} (114.94)	3.81^{c} (104.99)	2.42^{c} (165.29)	0.70 (571.42)	0.92 (434.78)	2.49 (160.64)	3.10 (129.03)
Once in three days	18.67 (21.42)	4.11 (97.32)	4.54^{c} (88.11)	7.61^{b} (52.56)	10.53^{b} (37.99)	6.24^{b} (64.10)	7.85^{b} (50.96)	4.38^{c} (91.32)	0.99 (404.04)	1.03 (388.35)	3.82 (104.71)	4.67 (85.65)
Once in six days	23.52 (17.00)	5.61 (71.30)	8.34^{b} (47.96)	12.48^{a} (32.05)	15.60^{b} (25.64)	33.76^{a} (11.85)	10.65^{b} (37.56)	14.85^{a} (26.94)	1.11 (360.36)	1.41 (283.69)	4.10 97.56)	7.23 (55.33)
P	NS		0.00		0.012		0.00		NS		NS	
Provenance Mean	15.94 (25.09)	4.27 (93.68)	5.80 (68.97)	7.84 (45.92)	11.90 (33.61)	14.49 (27.60)	7.44 (53.76)	7.22 (55.40)	0.94 (425.53)	1.12 (357.14)	3.47 (115.27)	5.00 (80.00)
P	NS		NS		NS		NS		NS		0.020	
SEm ±	7.586		1.703		8.84		1.806		0.664		1.608	

Values in parentheses are stomatal conductance in m mol m^{-2} s^{-1}

S – Shimoga provenance, M – Marayoor provenance

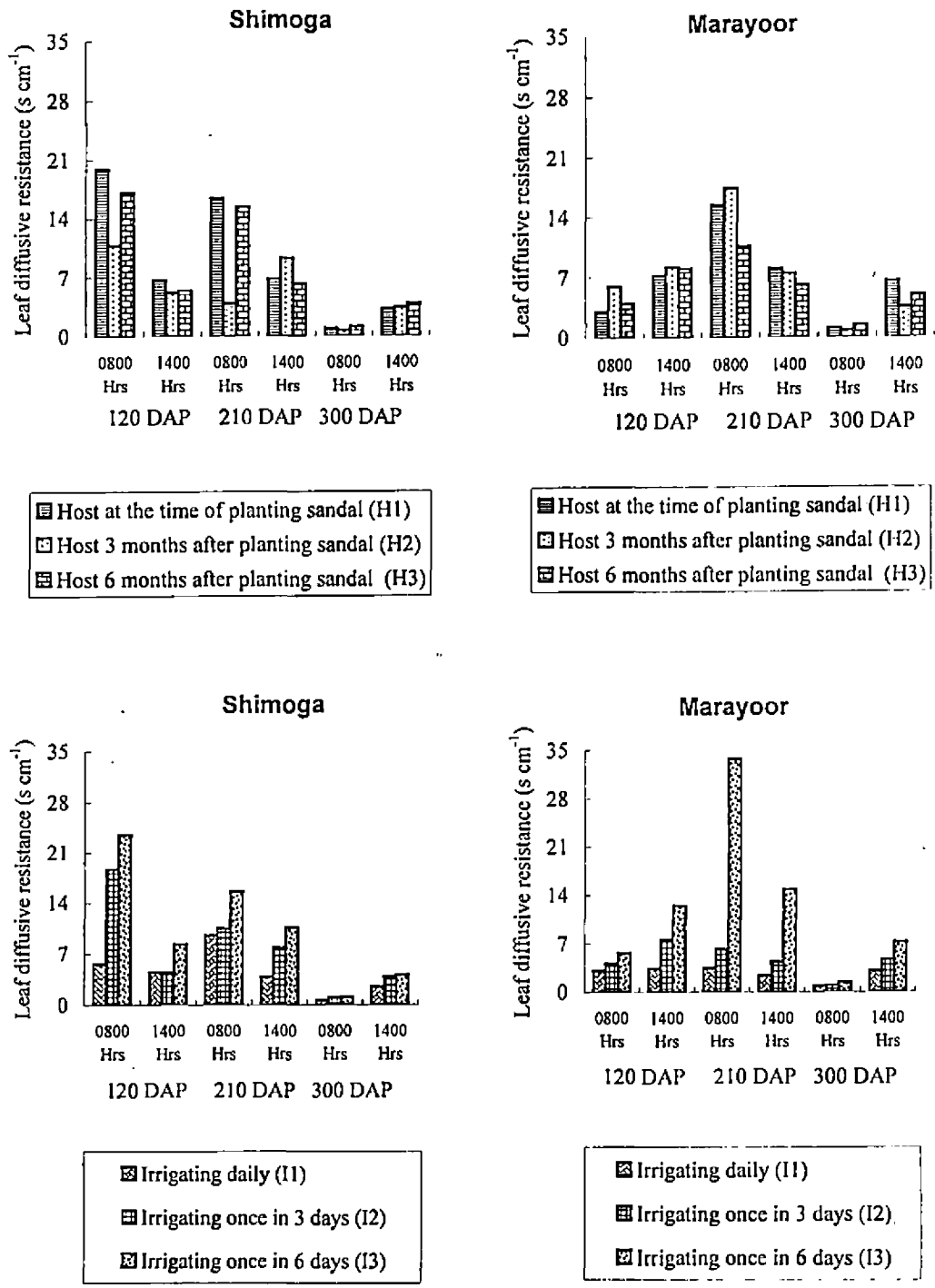


Fig. 10. Leaf diffusive resistance of sandal seedlings in Shimoga and Marayoor provenance as affected by stage of host introduction and levels of water stress

Table 26. Interaction effects of stage of host introduction and irrigation levels on the leaf diffusive resistance (s cm^{-1}) of sandal seedlings

Stage of host introduction	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
	120 Days after planting (0800 H)				120 Days after planting (1400 H)			
At the time of planting sandal	2.62 (152.67)	16.75 (23.88)	15.05 (26.58)	11.47 (34.87)	3.64 (109.89)	5.41 (73.94)	11.93 (33.53)	6.99 (57.22)
3 months after planting sandal	6.06 (66.00)	4.68 (85.47)	14.10 (28.37)	8.28 (48.31)	4.22 (94.79)	5.92 (67.57)	10.04 (39.84)	6.73 (59.44)
6 months after planting sandal	4.22 (94.79)	20.02 (19.98)	7.26 (55.10)	10.50 (38.10)	4.08 (98.04)	6.90 (65.68)	9.27 (43.15)	6.75 (59.26)
Mean	4.30 (93.02)	13.82 (28.94)	12.14 (32.95)		3.98 (100.50)	6.08 (65.79)	10.41 (38.42)	
P (0.05)	NS				NS			
SEm ±	7.59				1.70			
Stage of Host introduction	210 Days after planting (0800 H)				210 Days after planting (1400 H)			
At the time of planting sandal	9.00 (44.44)	10.48 (38.17)	28.33 (14.12)	15.94 (25.09)	2.77 (144.40)	6.24 (64.10)	13.35 (29.96)	7.45 (53.69)
3 months after planting sandal	3.82 (104.71)	7.56 (52.91)	20.53 (19.48)	10.64 (37.59)	3.33 (120.12)	6.51 (61.44)	15.32 (26.11)	8.39 (47.68)
6 months after planting sandal	6.55 (61.07)	14.73 (27.16)	17.58 (22.75)	12.95 (30.89)	3.26 (122.70)	5.59 (71.56)	9.59 (41.71)	6.15 (65.04)
Mean	6.46 (61.92)	10.92 (36.63)	22.15 (18.06)		3.12 (128.21)	6.11 (65.47)	12.75 (31.37)	
P (0.05)	NS				NS			
SEm ±	8.84				1.81			
Stage of Host introduction	300 Days after planting (0800 H)				300 Days after planting (1400 H)			
At the time of planting sandal	0.55 (727.27)	0.93 (430.11)	1.60 (250.00)	1.03 (388.35)	2.09^{f} (191.39)	4.79^{bc} (83.51)	7.74^{a} (51.68)	4.87 (82.14)
3 months after planting sandal	0.87 (459.77)	0.72 (555.55)	0.71 (563.38)	0.77 (519.48)	4.41^{bc} (90.70)	2.99^{e} (133.78)	2.97^{e} (134.68)	3.46 (115.61)
6 months after planting sandal	1.74 (229.89)	1.22 (327.87)	0.91 (439.56)	1.29 (310.08)	4.30^{c} (93.02)	4.96^{b} (80.65)	3.88^{d} (103.09)	4.38 (91.32)
Mean	1.05 (380.95)	0.96 (416.67)	1.07 (373.83)		3.60 (111.11)	4.25 (94.12)	4.86 (82.30)	
P (0.05)	NS				0.03			
SEm ±	0.663				1.61			

Values in parentheses are stomatal conductance in m mol m^{-2} s^{-1}

Table 27. Interaction effects of provenances, hosts and irrigation levels on leaf diffusive resistance (s cm^{-1}) at 0800 hrs of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	2.19 (182.65)	30.47 (13.13)	27.17 (14.72)	19.94 (20.07)	3.04 (131.57)	3.04 (95.24)	2.93 (136.52)	3.00 (133.34)
3 months after planting sandal	8.32 (48.08)	4.09 (97.80)	19.97 (20.03)	10.79 (37.08)	4.20 (95.24)	5.26 (76.05)	8.23 (48.61)	5.90 (67.80)
6 months after planting sandal	6.39 (62.60)	36.00 (11.12)	8.86 (45.15)	17.08 (23.42)	2.04 (196.08)	4.04 (99.01)	5.67 (70.55)	3.92 (102.05)
Mean	5.63 (71.05)	23.52 (17.01)	18.67 (21.43)		3.09 (129.44)	4.11 (97.33)	5.61 (79.85)	
P (0.05)	NS							
SEm ±	4.380							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	14.36 (27.86)	13.94 (28.7)	20.93 (19.12)	16.41 (24.38)	3.64 (109.90)	7.02 (59.99)	35.73 (11.20)	15.46 (25.88)
3 months after planting sandal	3.37 (118.70)	8.31 (48.14)	0.00 (***)	3.89 (102.83)	4.27 (93.68)	6.82 (58.66)	41.06 (9.75)	17.38 (23.02)
6 months after planting sandal	10.97 (36.47)	24.56 (16.29)	10.67 (37.48)	15.40 (25.98)	2.53 (158.11)	4.90 (81.64)	24.50 (16.33)	10.64 (37.60)
Mean	9.57 (41.80)	15.60 (25.64)	10.53 (37.99)		3.48 (114.94)	6.25 (64.00)	33.76 (11.85)	
P (0.05)	NS							
SEm ±	5.106							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	0.44 (909.09)	1.00 (400.00)	1.40 (285.72)	0.95 (421.06)	0.65 (615.38)	0.86 (465.12)	1.80 (222.22)	1.10 (363.64)
3 months after planting sandal	1.04 (384.62)	0.43 (930.24)	0.69 (579.72)	0.72 (555.56)	0.70 (571.43)	1.02 (392.16)	0.72 (555.55)	0.81 (493.83)
6 months after planting sandal	0.59 (677.97)	1.57 (254.78)	1.25 (320.00)	1.14 (350.87)	2.90 (137.93)	0.87 (459.77)	0.58 (689.66)	1.45 (275.86)
Mean	0.69 (579.72)	1.00 (400.00)	1.11 (360.37)		1.42 (281.69)	0.92 (434.78)	1.03 (388.35)	
P (0.05)	NS							
SEm ±	0.383							

Values in parentheses are stomatal conductance in m mol m^{-2} s^{-1}

Table 28. Interaction effects of provenances, hosts and irrigation levels on leaf diffusive resistance(s cm^{-2}) at 1400 hrs of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	4.47 (89.49)	4.15 (96.38)	11.56 (34.60)	6.72 (59.52)	2.82 (141.84)	6.66 (60.06)	12.29 (32.55)	7.25 (55.17)
3 months after planting sandal	4.44 (90.10)	5.01 (79.84)	6.21 (64.41)	5.22 (76.62)	4.00 (100.00)	6.83 (58.56)	13.87 (28.83)	8.23 (48.60)
6 months after planting sandal	4.62 (86.58)	4.46 (89.68)	7.26 (55.09)	5.44 (73.52)	3.54 (112.99)	9.34 (42.82)	11.27 (35.49)	8.05 (49.68)
Mean	4.51 (88.69)	4.54 (88.11)	8.34 (47.96)		3.45 (115.94)	7.61 (52.56)	12.47 (32.07)	
P (0.05)	NS							
SEm ±	0.984							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	3.00 (133.33)	8.22 (48.66)	9.27 (43.15)	6.83 (58.56)	2.54 (157.48)	4.26 (93.89)	17.43 (22.94)	8.07 (49.56)
3 months after planting sandal	4.47 (89.48)	8.24 (48.54)	15.17 (26.36)	9.29 (43.06)	2.18 (183.48)	4.78 (83.68)	15.47 (25.85)	7.47 (53.55)
6 months after planting sandal	3.96 (101.01)	7.08 (56.49)	7.51 (53.26)	6.18 (64.72)	2.55 (156.86)	4.10 (97.56)	11.66 (34.30)	6.10 (65.57)
Mean	3.81 (104.98)	7.84 (51.02)	10.15 (39.41)		2.42 (165.28)	4.38 (91.32)	14.85 (26.93)	
P (0.05)	NS							
SEm ±	1.043							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	1.45 (275.86)	5.66 (70.67)	2.47 (161.94)	3.19 (125.39)	2.72 (147.06)	3.92 (102.04)	13.00 (30.76)	6.54 (61.16)
3 months after planting sandal	4.61 (86.76)	2.99 (133.78)	2.55 (156.86)	3.38 (118.34)	4.21 (95.01)	2.99 (133.78)	3.38 (118.34)	3.52 (113.64)
6 months after planting sandal	6.22 (64.31)	2.80 (142.86)	2.46 (162.60)	3.82 (104.71)	2.38 (168.06)	7.11 (56.26)	5.30 (75.43)	4.93 (81.14)
Mean	4.09 (97.79)	3.81 (104.98)	2.49 (160.64)		3.10 (129.03)	4.67 (85.65)	7.22 (55.40)	
P (0.05)	0.02							
SEm ±	0.928							

Values in parentheses are stomatal conductance in m mol m^{-2} s^{-1}

leaf diffusive resistance of seedlings of Shimoga provenance was higher compared to seedlings of Marayoor provenance (Table 25).

The interaction effects of stage of host introduction and irrigation levels on the leaf diffusive resistance was significant only at 300 DAP at 1400 hrs (Table. 26). The leaf diffusive resistance was high in seedlings watered once in six days and where the host was introduced at the time of planting sandal.

Interaction of sandal provenances, stage of host introduction and levels of water stress on leaf diffusive resistance was highly significant at 300 DAP during the afternoon hour (Table 27 and 28). The interaction effect showed that leaf diffusive resistance was high in seedlings where the host was introduced at the time of planting sandal and irrigated once in six days in Marayoor provenance. Minimum leaf diffusive resistance was observed in seedlings where the host was introduced at the time of planting sandal and watered daily, in Shimoga provenance. The interactions of stage of host introduction and irrigation levels on the leaf diffusive resistance of sandal seedlings was significant only at 300 DAP at 1400 H (Table 28). The leaf diffusive resistance was high in seedlings watered once in six days and where the host was introduced at the time of planting sandal.

4.2.3 Transpiration rate

The transpiration rates of sandal seedlings recorded at 120, 210 and 300 DAP (at the end of water stress cycle) is shown in Table 29, 30, 31 and 32 and Fig. 11. Introduction of host at any of the stages did not show significant differences on the transpiration rate of sandal seedlings in both the provenances (Table. 29). As the levels of water stress increased, there was a decrease in the transpiration rate of the seedlings. At 120 DAP and 210 DAP the seedlings of Marayoor provenance were transpiring at a faster rate as compared to seedlings of Shimoga provenance. But a reverse pattern was observed at 300 DAP where the seedlings of Shimoga provenance were transpiring at a faster rate as compared to seedlings of Marayoor provenance.

The interaction effects of stage of host introduction and irrigation levels on the leaf diffusive resistance was not significant at any of the stages (Table. 30).

Table 29. Transpiration rate (μg H_2O cm^{-2} s^{-1}) in sandal seedlings as affected by stage of host introduction and different levels of water stress.

Provenances	Days after planting											
	120 DAP				210 DAP				300 DAP			
	S 0800 Hrs	M 0800 Hrs	S 1400 Hrs	M 1400 Hrs	S 0800 Hrs	M 0800 Hrs	S 1400 Hrs	M 1400 Hrs	S 0800 Hrs	M 0800 Hrs	S 1400 Hrs	M 1400 Hrs
Time of host introduction												
At the time of planting sandal	1.16	1.96	6.06	6.72	0.97	3.02	2.36	2.95	4.78	4.93	5.29	3.22
3 months after planting sandal	1.65	1.67	6.87	5.15	1.68	2.02	1.96	3.07	5.80	5.38	4.52	4.45
6 months after planting sandal	1.16	2.42	6.13	5.22	1.26	2.52	2.42	3.23	4.31	5.53	4.08	3.86
P	NS		NS		NS		NS		NS		NS	
Irrigation												
Daily	2.23^{a}	2.95^{a}	7.42^{b}	9.92^{a}	2.41^{b}	5.07^{a}	3.62^{b}	4.93^{a}	6.19^{ab}	7.28^{a}	5.34^{a}	4.87^{a}
Once in three days	0.99^{b}	2.17^{a}	7.01^{b}	4.17^{c}	1.30^{b}	1.93^{b}	1.83^{c}	3.47^{b}	4.64^{bc}	4.30^{c}	4.55^{a}	4.21^{a}
Once in six days	0.75^{b}	0.92^{b}	4.62^{c}	2.99^{c}	0.20^{b}	0.56^{b}	1.29^{c}	0.85^{c}	4.06^{c}	4.26^{c}	4.01^{b}	2.46^{b}
P	0.00		0.00		0.0003		0.00		0.0003		0.002	
Provenance Mean	1.32	2.01	6.35	5.70	1.30	2.52	4.24	3.08	4.96	5.28	4.63	3.85
P	NS		NS		NS		NS		NS		NS	
SEm ±	0.53		1.28		1.309		0.710		1.063		0.847	

S – Shimoga provenance
M – Marayoor provenance

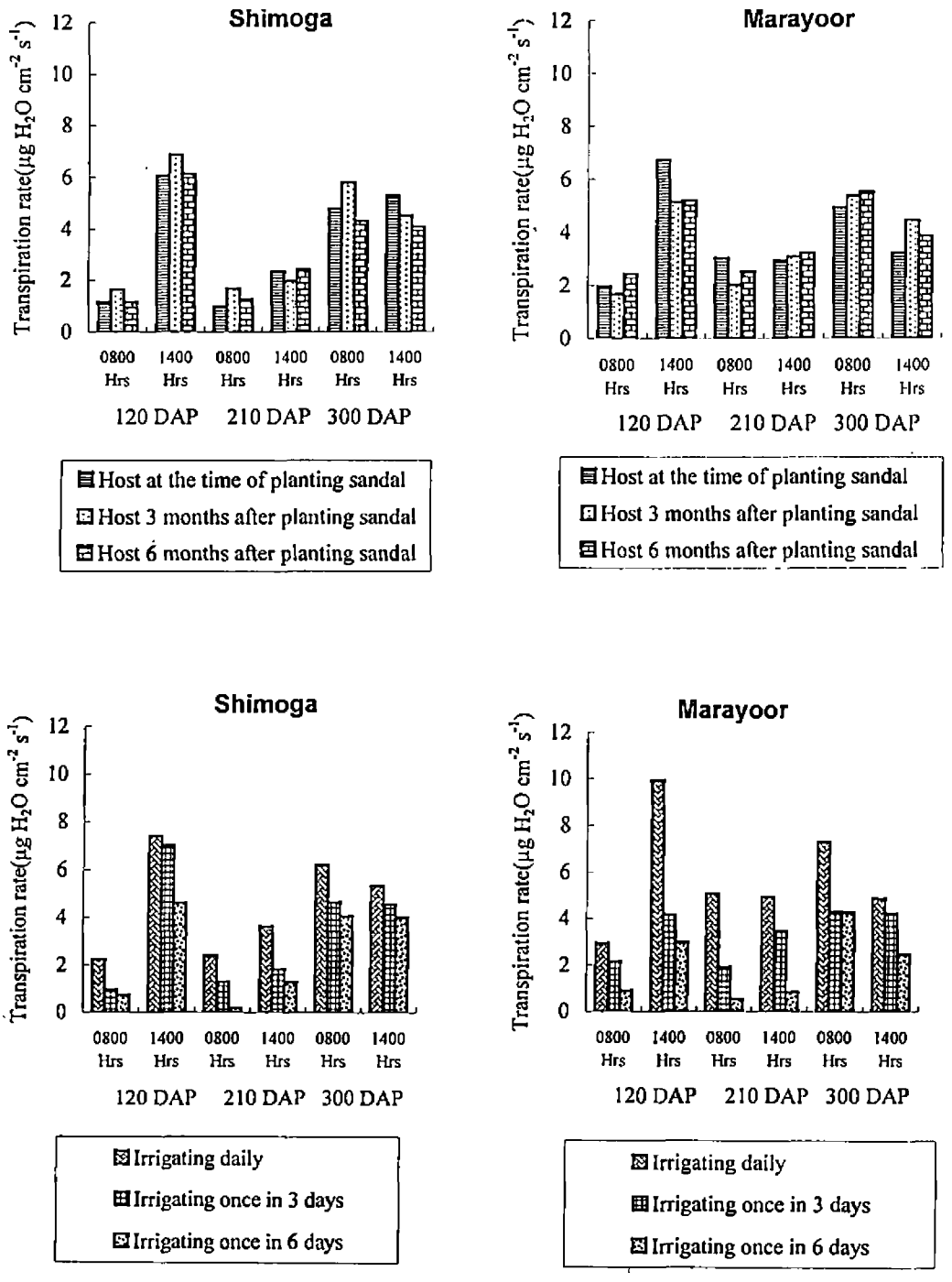


Fig. 11. Transpiration rate of sandal seedlings in Shimoga and Marayoor provenance as affected by stage of host introduction and levels of water stress

Table 30. Interaction effects of stage of host introduction and irrigation levels on the transpiration rate (μg H_2O cm^{-2} s^{-1}) of sandal seedlings

Stage of host introduction	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
	120 Days after planting (0800 H)				120 Days after planting (1400 H)			
At the time of planting sandal	3.02	1.38	0.28	1.56	10.27	5.83	3.06	6.39
3 months after planting sandal	2.03	1.70	1.25	1.66	7.99	5.44	4.61	6.01
6 months after planting sandal	2.72	1.29	1.35	1.79	7.76	5.51	3.75	5.67
Mean	2.59	1.46	0.96		8.67	5.59	3.81	
P (0.05)	NS				NS			
SEm ±	0.53				1.28			
Stage of Host introduction	210 Days after planting (0800 H)				210 Days after planting (1400 H)			
At the time of planting sandal	4.14	1.52	0.32	1.99	4.33	2.53	1.09	2.65
3 months after planting sandal	3.87	1.52	0.17	1.85	4.52	2.23	0.78	2.51
6 months after planting sandal	3.21	1.79	0.67	1.89	3.97	3.18	1.33	2.83
Mean	3.74	1.61	0.39		4.27	2.65	1.07	
P (0.05)	NS				NS			
SEm ±	1.31				0.71			
Stage of Host introduction	300 Days after planting (0800 H)				300 Days after planting (1400 H)			
At the time of planting sandal	6.66	4.28	3.63	4.86	6.06	3.91	2.80	4.26
3 months after planting sandal	7.28	5.34	4.15	5.59	4.66	5.33	3.48	4.49
6 months after planting sandal	6.28	3.73	4.76	4.92	4.60	3.90	3.41	3.97
Mean	6.74	4.45	4.18		5.11	4.38	3.23	
P (0.05)	NS				NS			
SEm ±	1.06				0.85			

Table 31. Interaction effects of provenances, hosts and irrigation levels on transpiration (g H_2O cm^{-2} s^{-1}) rate at 0800 hrs of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	3.19	0.25	0.05	1.16	2.86	2.51	0.50	1.96
3 months after planting sandal	1.34	1.80	1.81	1.65	2.72	1.59	0.69	1.67
6 months after planting sandal	2.17	0.19	1.11	1.16	3.27	2.41	1.58	2.42
Mean	2.23	0.75	0.99		2.95	2.17	0.92	
P (0.05)	NS							
SEm ±	0.306							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	1.63	1.11	0.17	0.97	6.65	1.94	0.46	3.02
3 months after planting sandal	3.74	1.30	0.00	1.68	4.00	1.73	0.33	2.02
6 months after planting sandal	1.87	1.48	0.44	1.26	4.55	2.11	0.90	2.52
Mean	2.41	1.30	0.20		5.07	1.93	0.56	
P (0.05)	NS							
SEm ±	0.756							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	6.35	3.69	4.30	4.78	6.97	4.88	2.95	4.93
3 months after planting sandal	6.32	6.84	4.23	5.80	8.23	3.84	4.06	5.38
6 months after planting sandal	5.91	3.38	3.64	4.31	6.64	4.07	5.87	5.53
Mean	6.19	4.64	4.06		7.28	4.26	4.29	
P (0.05)	NS							
SEm ±	0.614							

Table 32. Interaction effects of provenances, hosts and irrigation levels on transpiration (g H_2O cm^{-2} s^{-1}) rate at 1400 hrs of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	7.57	7.61	2.98	6.05	12.97	4.05	3.14	6.72
3 months after planting sandal	8.00	6.22	6.38	6.87	7.97	4.65	2.84	5.15
6 months after planting sandal	6.69	7.20	4.50	6.13	8.83	3.82	3.00	5.22
Mean	7.42	7.01	4.62		9.92	4.17	2.99	
P (0.05)	NS							
SEm ±	0.739							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	3.87	1.76	1.43	2.35	4.79	3.29	0.76	2.95
3 months after planting sandal	3.59	1.55	0.73	1.96	5.46	2.91	0.83	3.06
6 months after planting sandal	3.41	2.16	1.70	2.42	4.53	4.19	0.96	3.23
Mean	3.62	1.82	1.29		4.93	3.46	0.85	
P (0.05)	NS							
SEm ±	0.410							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	7.22	4.63	4.03	5.29	4.90	3.20	1.57	3.22
3 months after planting sandal	4.72	4.84	4.01	4.52	4.59	5.82	2.95	4.45
6 months after planting sandal	4.09	4.18	3.97	4.08	5.12	3.61	2.85	3.86
Mean	5.34	4.55	4.00		4.87	4.21	2.46	
P (0.05)	NS							
SEm ±	0.489							

Interactions of sandal provenances, stage of host introduction and levels of water stress on the transpiration rate at both 0800 hrs and 1400 hrs (Table. 31 and 32) was not significant at any of the stages (120, 210 and 300 DAP).

4.2.4 Leaf temperature

The leaf temperature of sandal seedlings recorded at 120, 210 and 300 DAP (at the end of water stress cycle) is shown in Table 33, 34, 35 and 36 and Fig. 12. The stages of host introduction showed significant effect on the leaf temperature of sandal seedlings at 210 DAP and 300 DAP. Seedlings of Shimoga provenance showed a lower leaf temperature as compared to seedlings of Marayoor provenance irrespective of stage of host introduction. The seedlings of Marayoor provenance, where host was introduced at the time of planting sandal showed a higher leaf temperature at 300 DAP at 0800 hrs whereas seedlings where the host was introduced six months after planting sandal showed highest leaf temperature at 1400 hrs (Table. 33). The levels of water stress showed a significant effect on the leaf temperature only at 300 DAP at 0800 hrs. The seedlings of Marayoor provenance recorded a higher leaf temperature as compared to seedlings of Shimoga provenance.

The interaction effects of stage of host introduction and irrigation levels on the leaf temperature of sandal seedlings was not significant at any of the stages (Table 34).

Interaction of sandal provenances, stage of host introduction and levels of water stress were significant at 210 and 300 DAP (Table 35 and 36). The seedlings of Shimoga provenance showed a higher leaf temperature as compared to seedlings of Marayoor provenances. Seedlings of Shimoga provenance where the host was introduced six months after planting sandal and irrigated daily recorded highest leaf temperature, whereas seedlings of Marayoor provenance where the host was introduced at the time of planting sandal and irrigated once in three days had lowest leaf temperature. At 300 DAP the seedlings of Shimoga provenance where host was introduced six months after planting sandal and watered daily showed highest leaf temperature whereas seedlings of Marayoor provenance, which were watered once in three days and host introduced six months after planting sandal recorded the lowest leaf temperature.

Table 33. Leaf temperature (°C) in sandal seedlings as affected by stage of host introduction and different levels of water stress.

Provenances	Days after planting											
	120 DAP				210 DAP				300 DAP			
	S	M	S	M	S	M	S	M	S	M	S	M
	0800 Hrs	0800 Hrs	1400 Hrs	1400 Hrs	0800 Hrs	0800 Hrs	1400 Hrs	1400 Hrs	0800 Hrs	0800 Hrs	1400 Hrs	1400 Hrs
Time of host introduction												
At the time of planting sandal	25.46	26.14	36.69	36.21	31.41^{b}	33.00^{c}	32.97	32.54	27.48^{cd}	28.19^{a}	31.86^{c}	31.61^{b}
3 months after planting sandal	25.46	26.26	36.83	36.13	30.94^{b}	32.50^{a}	33.03	32.66	27.36^{d}	27.78^{b}	31.74^{c}	31.63^{bc}
6 months after planting sandal	25.44	26.12	36.72	36.24	30.94^{b}	32.46^{a}	33.19	32.63	27.47^{cd}	27.72^{bc}	32.03^{d}	31.14^{a}
P	NS		NS		0.015		NS		0.010		0.038	
Irrigation												
Daily	25.46	26.17	36.68	36.23	31.26	32.66	33.08	32.59	27.50^{b}	28.13^{a}	32.01	31.40
Once in three days	25.46	26.10	36.62	36.21	31.10	32.68	32.99	32.61	27.38^{b}	27.96^{a}	31.93	31.28
Once in six days	25.44	26.26	36.94	36.14	30.94	32.62	33.12	32.63	27.42^{b}	27.60^{b}	31.69	31.71
P	NS		NS		NS		NS		0.007		NS	
Provenance Mean	25.45	26.17	36.75	36.19	31.10	32.65	33.06	32.61	27.44	27.89	31.88	31.46
P	0.326		NS		NS		NS		NS		0.019	
SEm ±	0.241		0.176		0.323		0.123		0.156		0.096	

S – Shimoga provenance
M – Marayoor provenance

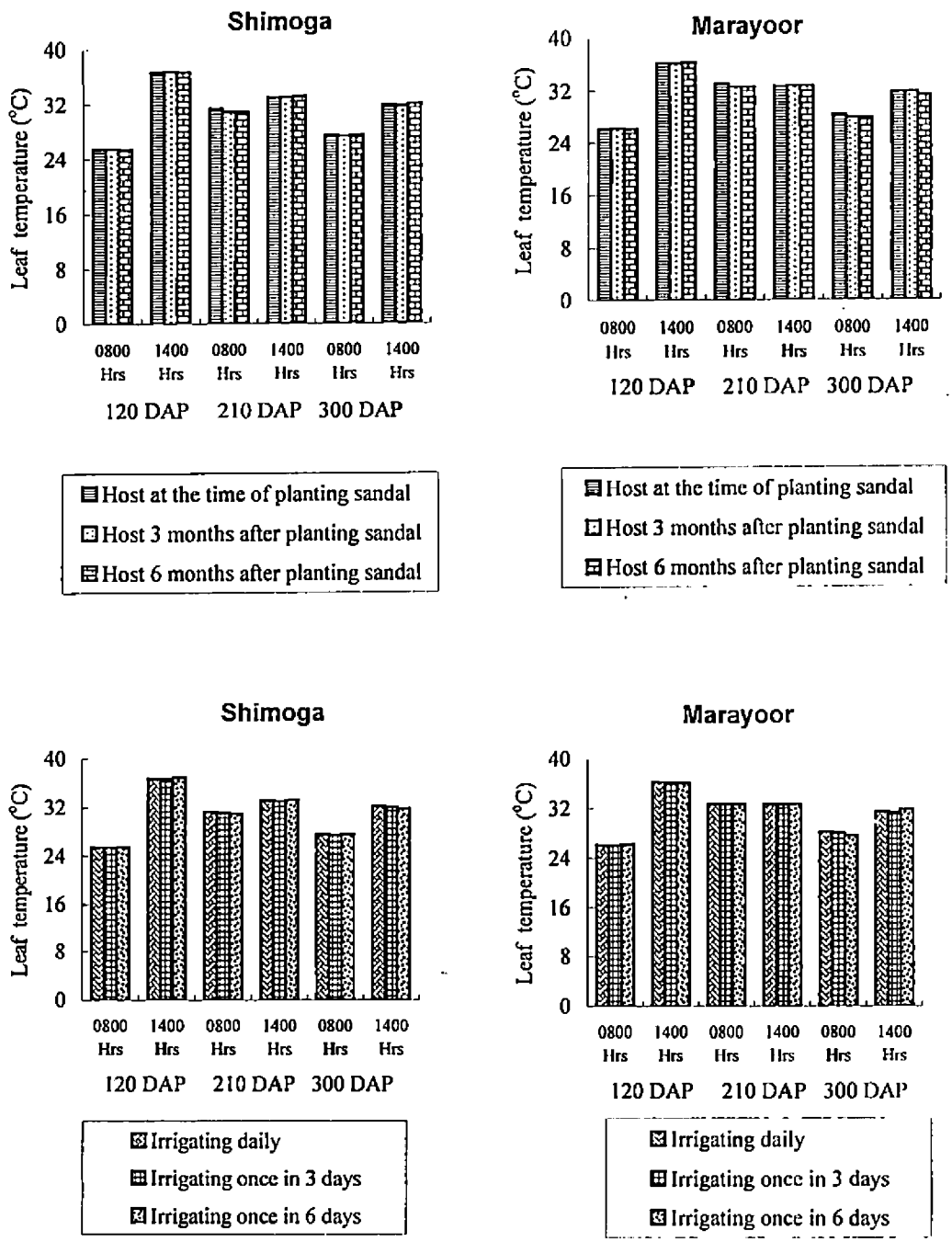


Fig. 12. Leaf temperature of sandal seedlings in Shimoga and Marayoor provenance as affected by stage of host introduction and levels of water stress

Table 34. Interaction effects of stage of host introduction and irrigation levels on the leaf temperature (^{0}C) of sandal seedlings

Stage of host introduction	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
	120 Days after planting (0800 H)				120 Days after planting (1400 H)			
At the time of planting sandal	25.90	25.70	25.80	25.80	36.53	36.28	36.53	36.45
3 months after planting sandal	26.00	25.85	25.72	25.86	36.45	36.50	36.50	36.48
6 months after planting sandal	25.53	25.78	26.03	25.78	36.38	36.47	36.60	36.48
Mean	25.81	25.78	25.85		36.45	36.42	36.54	
P (0.05)	NS				NS			
SEm ±	0.241				0.530			
Stage of Host introduction	210 Days after planting (0800 H)				210 Days after planting (1400 H)			
At the time of planting sandal	32.37	32.27	31.98	32.21	32.73	32.73	32.80	32.75
3 months after planting sandal	31.73	31.80	31.63	31.72	32.77	32.73	33.03	32.84
6 months after planting sandal	31.77	31.60	31.73	31.70	33.00	32.93	32.80	32.91
Mean	31.96	31.89	31.78		32.83	32.80	32.88	
P (0.05)	NS				NS			
SEm ±	0.323				0.123			
Stage of Host introduction	300 Days after planting (0800 H)				300 Days after planting (1400 H)			
At the time of planting sandal	28.03	27.98	27.48	27.83	31.58^{bc}	31.85^{a}	31.77^{abc}	31.73
3 months after planting sandal	27.70	27.50	27.50	27.57	31.80^{ab}	31.70^{abc}	31.57^{c}	31.69
6 months after planting sandal	27.72	27.52	27.55	27.60	31.73^{abc}	31.27^{d}	31.77^{abc}	31.59
Mean	27.82	27.67	27.51		31.70	31.61	31.70	
P (0.05)	NS				0.0000			
SEm ±	0.156				0.096			

Table 35. Interaction effects of provenances, hosts and irrigation levels on leaf temperature (^{0}C) at 0800 hrs of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	25.43	25.50	25.43	25.45	26.37	25.90	26.17	26.15
3 months after planting sandal	25.50	25.47	25.40	25.46	26.50	26.23	26.03	26.25
6 months after planting sandal	25.43	25.40	25.50	25.44	25.63	26.17	26.57	26.12
Mean	25.45	25.46	25.44		26.16	26.10	26.26	
P (0.05)	NS							
SEm ±	0.139							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	31.90	31.30	31.03	31.41	32.83	33.23	32.93	33.00
3 months after planting sandal	30.90	31.03	30.90	30.94	32.57	32.57	32.37	32.50
6 months after planting sandal	30.97	30.97	30.90	30.94	32.57	32.23	32.57	32.46
Mean	31.26	31.10	30.94		32.66	32.68	32.62	
P (0.05)	NS							
SEm ±	0.187							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	27.43	27.57	27.43	27.48	28.63	28.40	27.53	28.19
3 months after planting sandal	27.43	27.23	27.40	27.35	27.97	27.77	27.60	27.78
6 months after planting sandal	27.63	27.33	27.43	27.46	27.80	27.70	27.67	27.72
Mean	27.50	27.38	27.42		28.13	27.96	27.60	
P (0.05)	NS							
SEm ±	0.090							

Table 36. Interaction effects of provenances, hosts and irrigation levels on leaf temperature (^{0}C) at 1400 hrs of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	36.77	36.47	36.83	36.69	36.30	36.10	36.23	36.21
3 months after planting sandal	36.63	36.83	37.03	36.83	36.27	36.17	35.97	36.14
6 months after planting sandal	36.63	36.57	36.97	36.72	36.13	36.37	36.23	36.24
Mean	36.68	36.62	36.94		36.23	36.21	36.14	
P (0.05)	NS							
SEm ±	0.102							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	32.90	32.97	33.03	32.97	32.57	32.50	32.57	32.55
3 months after planting sandal	32.90	32.83	33.37	33.03	32.63	32.63	32.70	32.65
6 months after planting sandal	33.43	33.17	32.97	33.19	32.57	32.70	32.63	32.63
Mean	33.08	32.99	33.12		32.59	32.61	32.63	
P (0.05)	NS							
SEm ±	0.071							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	31.83	31.97	31.77	31.86	31.33	31.73	31.73	31.61
3 months after planting sandal	31.93	31.87	31.43	31.74	31.67	31.53	31.70	31.63
6 months after planting sandal	32.27	31.97	31.87	32.04	31.20	30.57	31.67	31.15
Mean	32.01	31.94	31.69		31.40	31.28	31.71	
P (0.05)	0.02							
SEm ±	0.055							

4.2.5 Chlorophyll content

Chlorophyll 'a', chlorophyll 'b' and total chlorophyll content of sandal seedlings at 120, 210 and 300 DAP are shown in Table 37, 38, 39, 40, 41, 42 and 43 and Fig. 13.

4.2.5.1 Chlorophyll 'a'

At all the three stages of sampling chlorophyll 'a' content was high in seedlings where the host was introduced at the time of planting sandal in both the provenances (Table 37). At 120 DAP the Marayoor seedlings had higher chlorophyll 'a' than Shimoga provenance at all the stages of host introduction. At 300 DAP the seedlings of Shimoga provenance had higher chlorophyll 'a' content than seedlings of Marayoor provenance where the host was introduced at the time of planting sandal. As the levels of water stress increased there was a decrease in the chlorophyll 'a' content of the seedlings and was significantly different at 120 DAP. The seedlings of Shimoga provenance had higher chlorophyll 'a' content as compared to seedlings of Marayoor provenance. Even though the increase in water stress decreased the chlorophyll 'a' content at 210 and 300 DAP, they were not significantly different.

The interaction effects of stage of host introduction and irrigation levels on the chlorophyll 'a' content of sandal seedlings were significant at all the stages (Table 38). At 120 DAP the seedlings watered daily and once in six days had higher chlorophyll 'a' content. At 210 and 300 DAP as the levels of water stress increased there was a decrease in the chlorophyll 'a' content of the leaves irrespective of stage of host introduction.

Interaction of sandal provenances, stage of host introduction and levels of water stress on chlorophyll 'a' content were highly significant at 120 DAP (Table 39). The seedlings watered once in six days and where the host was introduced at the time of planting sandal had highest chlorophyll content, followed by seedlings watered once in three days. At 120 and 210 DAP the seedlings where the host was introduced at the time of planting sandal had highest chlorophyll 'a' content.

Table 37. Chlorophyll content (mg g^{-1}) of sandal seedlings as affected by stage of host introduction and different levels of water stress

Provenances	Days after planting																	
	120 DAP						210 DAP						300 DAP					
	Chl 'a'		Chl 'b'		Total Chl		Chl 'a'		Chl 'b'		Total Chl		Chl 'a'		Chl 'b'		Total Chl	
	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M
Time of host introduction																		
At the time of planting sandal	9.57^{b}	11.75^{a}	4.07^{b}	5.14^{a}	13.63^{b}	16.88^{a}	11.73	11.67	5.79	6.77	17.51	18.44	10.93	10.41	6.70^{a}	6.45^{a}	17.62	16.86
3 months after planting sandal	9.57^{b}	7.02^{d}	3.71^{b}	2.60^{c}	13.29^{b}	9.62^{d}	10.98	10.68	5.26	6.09	16.23	16.77	9.81	10.62	6.10^{a}	6.03^{a}	15.91	16.64
6 months after planting sandal	8.39^{c}	7.80^{cd}	2.59^{c}	1.93^{c}	10.99^{c}	9.72^{cd}	8.94	8.99	3.76	4.86	12.69	13.84	9.60	10.54	4.90^{b}	6.56^{a}	14.49	17.10
P	0.00		0.00		0.00		NS		NS		NS		NS		0.00		NS	
Irrigation																		
Daily	10.84^{a}	9.15^{b}	4.02^{a}	2.92^{b}	14.86^{a}	12.07^{b}	13.27	12.17	6.34	7.00	19.60	19.16	12.54	12.55	7.33	7.36	19.86	19.91
Once in three days	8.09^{c}	9.27^{b}	3.41^{ab}	3.33^{ab}	11.50^{b}	12.59^{b}	8.86	9.92	4.30	5.44	13.16	15.35	9.58	9.57	5.72	6.12	15.29	15.69
Once in six days	8.60^{bc}	8.14^{c}	2.94^{b}	3.42^{ab}	11.54^{b}	11.56^{b}	9.51	9.26	4.16	5.28	13.67	14.54	8.22	9.46	4.65	5.56	12.87	15.01
P	0.00		0.03		0.00		NS		NS		NS		NS		NS		NS	
Provenance Mean	9.18	8.86	3.46	3.22	12.64	12.07	10.55	10.45	4.94	5.9	15.48	16.35	10.11	10.53	5.90	6.35	16.01	16.86
P	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.13		0.01	
SEm ±	0.572		0.49		0.782		0.919		0.63		1.422		0.615		0.492		0.989	

S – Shimoga provenance
M – Marayoor provenance

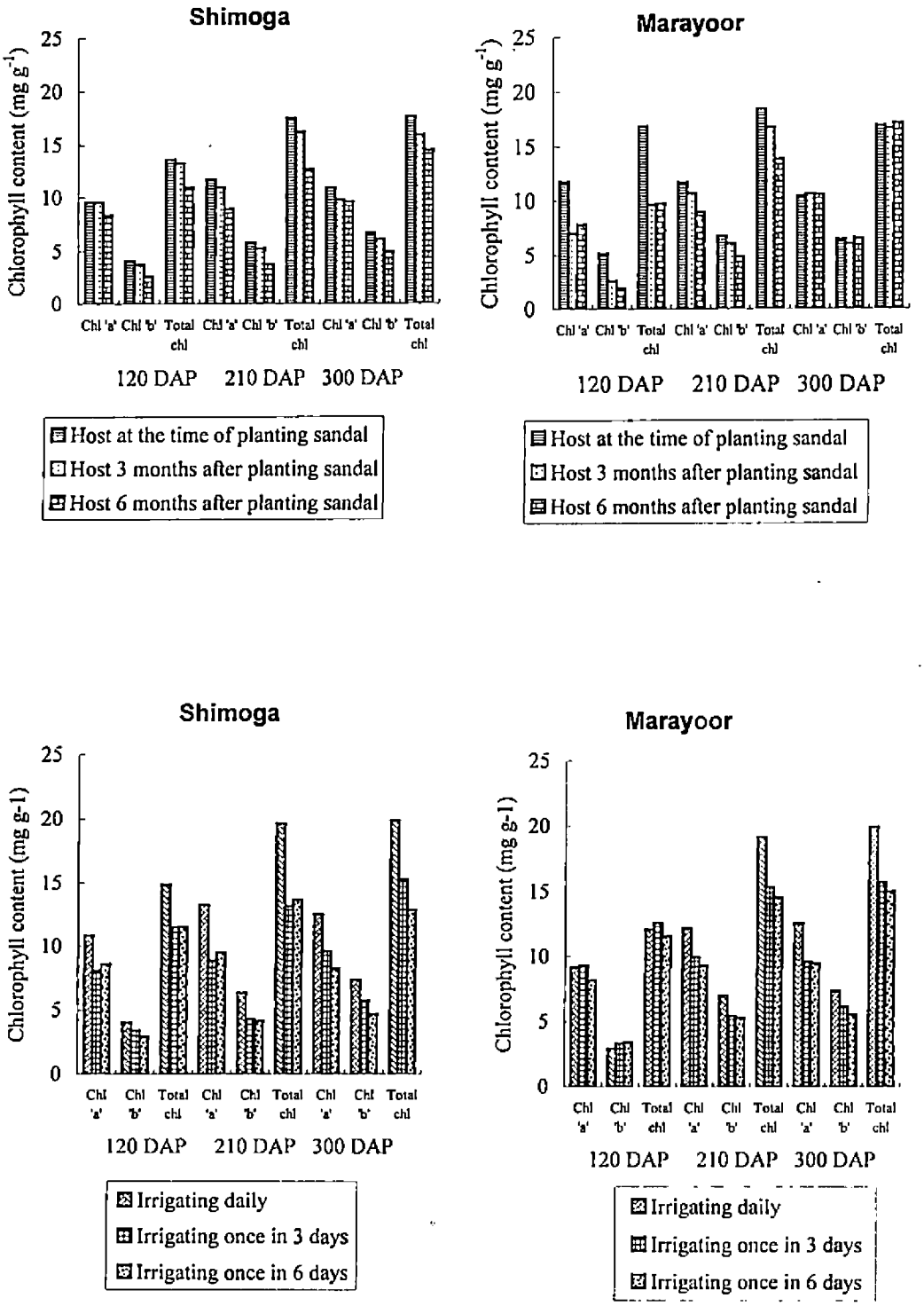


Fig. 13. Chlorophyll content of sandal seedlings in Shimoga and Marayoor provenance as affected by stage of host introduction and levels of water stress

Table 38. Interaction effects of stage of host introduction and irrigation levels on chlorophyll 'a' content (mg g^{-1}) of sandal seedlings

Stage of host introduction	Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean
	120 Days after planting			
At the time of planting sandal	-1.54^{d}	-1.58^{d}	-1.68^{bc}	-1.60
3 months after planting sandal	-1.63^{cd}	-1.78^{a}	-1.74^{d}	-1.65
6 months after planting sandal	-1.62^{cd}	-1.74^{ab}	-1.56^{d}	-1.64
Mean	-1.59	-1.70	-1.60	
P (0.05)	0.000			
SEm ±	0.437			
Stage of Host introduction	210 Days after planting			
At the time of planting sandal	-2.32^{de}	-2.43^{cd}	-2.62^{b}	-2.46
3 months after planting sandal	-2.23^{e}	-2.47^{c}	-2.70^{b}	-2.46
6 months after planting sandal	-2.41^{cd}	-2.40^{cd}	-2.92^{a}	-2.57
Mean	-2.32	-2.43	-2.75	
P (0.05)	0.001			
SEm ±	0.591			
Stage of Host introduction	300 Days after planting			
At the time of planting sandal	-2.10	-2.24	-2.31	-2.21
3 months after planting sandal	-2.05	-2.25	-2.30	-2.20
6 months after planting sandal	-1.98	-2.20	-2.32	-2.17
Mean	-2.04	-2.23	-2.31	
P (0.05)	NS			
SEm ±	0.716			

Table 39. Interaction effects of provenances, hosts and irrigation levels on Chlorophyll 'a' content (mg g^{-1}) of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	11.43^{ab}	10.73^{bc}	6.54^{fg}	9.57	11.57^{ab}	12.89^{a}	10.79^{bc}	11.75
3 months after planting sandal	11.12^{abc}	9.44^{cde}	8.16^{ef}	9.57	10.08^{bcd}	8.56^{de}	2.43^{i}	7.02
6 months after planting sandal	9.97^{bcd}	4.11^{h}	11.11^{abc}	8.40	5.82^{g}	6.37^{g}	11.21^{abc}	7.80
Mean	10.84	8.09	8.60		9.16	9.27	8.14	
P (0.05)	0.00							
SEm ±	0.330							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	12.50	12.02	10.66	11.73	11.58	11.37	12.07	11.67
3 months after planting sandal	15.36	6.30	11.27	10.98	12.95	9.29	9.81	10.68
6 months after planting sandal	11.95	8.26	6.61	8.94	11.99	9.10	5.88	8.99
Mean	13.27	8.86	9.51		12.17	9.92	9.25	
P (0.05)	NS							
SEm ±	0.531							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	12.31	10.48	9.99	10.93	11.73	9.56	9.95	10.41
3 months after planting sandal	13.34	8.53	7.55	9.81	13.40	8.64	9.81	10.62
6 months after planting sandal	11.96	9.73	7.11	9.60	12.51	10.50	8.61	10.54
Mean	12.54	9.58	8.22					
P (0.05)	NS							
SEm ±	0.355							

4.2.5.2 Chlorophyll 'b'

The chlorophyll 'b' content in sandal leaves showed significant variations at 120 and 300 DAP due to the stage of host introduction (Table 37). At 120 DAP, the seedlings of Marayoor provenance where the host was introduced at the time of planting sandal had higher chlorophyll 'b' content. At 300 DAP, except in seedlings of Shimoga provenance where the host was introduced six months after planting sandal, the chlorophyll 'b' content was similar irrespective of the stages of host introduction in both the provenances. As the level of water stress increased there was a decrease in the chlorophyll 'b' content and this effect was more prominent at 120 DAP. As the levels of water stress increased, there was a decrease in the chlorophyll 'b' content of the seedlings. The same trend was followed at 210 and 300 DAP but were not significantly different.

The interaction effects of stage of host introduction and irrigation levels on the chlorophyll 'b' content of sandal seedlings was significant only at 120 and 210 DAP (Table 40). At 120 DAP as the level of water stress increased, there was a decrease in the chlorophyll 'b' content of the seedlings irrespective of stage of host introduction. At 210 DAP all the seedlings watered daily had higher chlorophyll 'b' content as compared to seedlings watered once in three or six day.

Interaction of sandal provenances, stages of host introduction and levels of water stress on chlorophyll 'b' content were highly significant at 210 DAP. (Table 41) The content was high in seedlings of Marayoor provenance where the host was introduced at the time of planting sandal and watered daily. The lowest chlorophyll 'b' content was observed in Shimoga provenance where the host was introduced six months after planting sandal and watered once in three days.

4.2.5.3 Total chlorophyll

The total chlorophyll content varied significantly due to the introduction of host only at 120 DAP (Table 37). The seedlings where the host was introduced at the time of planting sandal had higher total chlorophyll in both the provenances as

Table 40. Interaction effects of stage of host introduction and irrigation levels on chlorophyll 'b' content (mg g^{-1}) of sandal seedlings

Stage of host introduction	Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean
	120 Days after planting			
At the time of planting sandal	5.34[a]	5.68[a]	2.78[c]	4.60
3 months after planting sandal	3.46[bc]	3.42[bc]	2.61[c]	3.16
6 months after planting sandal	1.61[d]	1.02[d]	4.16[b]	2.26
Mean	3.47	3.37	3.18	
P (0.05)	0.00			
SEm ±	0.491			
Stage of Host introduction	210 Days after planting			
At the time of planting sandal	6.80[a]	6.18[a]	5.86[a]	6.28
3 months after planting sandal	6.88[a]	4.46[bc]	5.68[ab]	5.67
6 months after planting sandal	6.33[a]	3.97[c]	2.62[d]	4.31
Mean	6.67	4.87	4.72	
P (0.05)	0.006			
SEm ±	0.630			
Stage of Host introduction	300 Days after planting			
At the time of planting sandal	7.52	6.14	6.08	6.58
3 months after planting sandal	7.66	5.67	4.86	6.06
6 months after planting sandal	6.86	5.96	4.38	5.73
Mean	7.35	5.92	5.11	
P (0.05)	NS			
SEm ±	0.492			

Table 41. Interaction effects of provenances, hosts and irrigation levels on Chlorophyll b' content (mg g^{-1}) of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	5.46	5.07	1.68	4.07	5.23	6.29	3.89	5.14
3 months after planting sandal	3.90	4.00	3.24	3.71	3.01	2.83	1.97	2.60
6 months after planting sandal	2.69	1.17	3.91	2.59	0.53	0.86	4.40	1.93
Mean	4.02	3.41	2.94		2.92	3.33	3.42	
P (0.05)	NS							
SEm ±	0.283							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	5.85^{abc}	6.53^{abc}	4.98^{bcde}	4.98	7.74^{a}	5.83^{abc}	6.74^{abc}	6.77
3 months after planting sandal	6.76^{abc}	3.17^{ef}	5.84^{abc}	5.84	7.00^{ab}	5.75^{abc}	5.53^{bcd}	6.09
6 months after planting sandal	6.41^{abc}	3.21^{ef}	1.65^{f}	1.65	6.25^{abc}	4.74^{cde}	3.59^{def}	4.86
Mean	6.34	4.30	4.16		7.00	5.44	5.29	
P (0.05)	0.02							
SEm ±	0.364							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	7.91	6.25	5.96	6.71	7.12	6.03	6.21	6.45
3 months after planting sandal	8.05	5.44	4.81	6.10	7.27	5.90	4.91	6.03
6 months after planting sandal	6.02	5.47	3.19	4.89	7.69	6.44	5.56	6.56
Mean	7.33	5.72	4.65		7.36	6.12	5.56	
P (0.05)	NS							
SEm ±	0.284							

compared to seedlings where the host was introduced three and six months after planting sandal. The water stress showed a significant reduction in the total chlorophyll content at 120 DAP. The increase in water stress decreased the total chlorophyll content. The same trend was followed at 210 and 300 DAP but were not significantly different.

The interaction effects of stage of host introduction and irrigation levels on the total chlorophyll of sandal seedlings were significant at all the stages (Table 42). At 120 DAP the seedlings watered once in three days and once in six days and where the host was introduced three and six months after planting sandal respectively had lower total chlorophyll content. At 210 and 300 DAP as the levels of water stress increased there was a decrease in the total chlorophyll content irrespective of stage of host introduction.

Interaction of sandal provenances, stage of host introduction and levels of water stress on total chlorophyll were highly significant at 120 and 300 DAP (Table 43). At 120 DAP the seedlings where the host was introduced at the time of planting sandal and irrigated once in three days had highest total chlorophyll in Marayoor provenance. Seedlings irrigated daily and where the host was introduced at the time of planting sandal had higher total chlorophyll in Shimoga provenance. The least total chlorophyll content was observed in Marayoor where the seedlings were watered once in three days and host introduced three months after planting sandal. At 300 DAP the seedlings of Shimoga provenance which were watered daily and host introduced three months after planting had highest total chlorophyll, whereas seedlings in Shimoga provenance which were watered daily and host introduced six months after planting sandal had lower total chlorophyll as compared to the total chlorophyll of the seedlings watered daily irrespective of the stage of host introduction. In both the provenances, the increase in water stress and the introduction of host at later stages decreased the total chlorophyll and was more prominent in Shimoga provenance.

4.3 PLANT NUTRIENT CONTENT

4.3.1 Nitrogen

The N content of sandal seedlings at 120, 210 and 300 DAP are shown in Table 44, 45 and 46 and Fig. 14. Highest N content was observed in Marayoor

Table 42. Interaction effects of stage of host introduction and irrigation levels on total chlorophyll content (mg g^{-1}) of sandal seedlings

Stage of host introduction	Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean
	120 Days after planting			
At the time of planting sandal	16.84^{ab}	17.49^{a}	11.44^{d}	15.26
3 months after planting sandal	14.05^{c}	12.41^{d}	7.90^{f}	11.45
6 months after planting sandal	9.51^{e}	6.25^{g}	15.31^{bc}	10.36
Mean	13.47	12.05	11.55	
P (0.05)	0.00			
SEm ±	0.782			
Stage of Host introduction	210 Days after planting			
At the time of planting sandal	18.83^{ab}	17.86^{b}	17.22^{b}	17.97
3 months after planting sandal	21.02^{a}	12.25^{e}	16.22^{b}	16.50
6 months after planting sandal	18.29^{ab}	12.65^{e}	8.87^{d}	13.27
Mean	19.38	14.25	14.10	
P (0.05)	0.00			
SEm ±	1.42			
Stage of Host introduction	300 Days after planting			
At the time of planting sandal	19.53^{a}	16.15^{b}	16.05b	17.24
3 months after planting sandal	21.03^{a}	14.25^{bc}	13.54c	16.27
6 months after planting sandal	19.09^{a}	16.07b	12.23c	15.80
Mean	19.88	15.49	13.94	
P (0.05)	0.00			
SEm ±	0.99			

Table 43. Interaction effects of provenances, hosts and irrigation levels on total chlorophyll content (mg g^{-1}) of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	16.88^{b}	15.8^{bc}	8.22^{g}	13.63	16.79^{b}	19.17^{a}	14.66^{bcde}	16.87
3 months after planting sandal	15.02^{bcde}	13.44^{cdef}	11.40^{f}	13.29	13.08^{def}	11.39^{f}	4.40^{i}	9.62
6 months after planting sandal	12.66^{ef}	5.28^{hi}	15.02^{bcde}	10.99	6.35^{ghi}	7.22^{gh}	15.61^{bcd}	9.73
Mean	14.85	11.51	11.55		12.07	12.59	11.56	
P (0.05)	0.00							
SEm ±	0.451							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	18.35	18.54	15.64	17.51	19.31	17.19	18.80	18.43
3 months after planting sandal	22.11	9.47	17.10	16.23	19.94	15.03	15.34	16.77
6 months after planting sandal	18.35	11.46	8.26	12.69	18.23	13.83	9.47	13.84
Mean	19.60	13.16	13.67		19.16	15.35	14.54	
P (0.05)	NS							
SEm ±	0.821							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	20.21^{ab}	16.72^{cde}	15.94^{cde}	17.62	18.86^{abc}	15.58^{def}	16.15^{cde}	16.86
3 months after planting sandal	21.39^{a}	13.97^{ef}	12.36^{fg}	15.91	20.67^{ab}	14.54^{ef}	14.72^{def}	16.64
6 months after planting sandal	17.98^{bcd}	15.19^{def}	10.30^{g}	14.49	20.20^{ab}	16.94^{cde}	14.17^{ef}	17.10
Mean	19.86	15.29	12.87		19.91	15.69	15.01	
P (0.05)	0.01							
SEm ±	0.571							

Table 44. N, P and K content (%) of sandal seedlings as affected by stage of host introduction and different levels of water stress

Provenances	Days after planting																	
	120 DAP						210 DAP						300 DAP					
	S-N	M-N	S-P	M-P	S-K	M-K	S-N	M-N	S-P	M-P	S-K	M-K	S-N	M-N	S-P	M-P	S-K	M-K
Stage of Host introduction																		
At the time of planting sandal	0.49	2.93	0.35	0.42	0.61	0.57	0.44^{b}	0.54^{a}	0.46^{a}	0.42^{d}	0.66^{ab}	0.630^{b}	0.35	0.43	0.41	0.44	8.55	0.54
3 months after planting sandal	0.52	3.09	0.41	0.37	0.56	0.60	0.44^{b}	0.43^{b}	0.44^{b}	0.38^{f}	0.65^{ab}	0.60^{b}	0.37	0.40	0.44	0.44	0.55	0.58
6 months after planting sandal	0.55	3.28	0.38	0.38	0.61	0.55	0.42^{b}	0.39^{b}	0.43^{c}	0.39^{e}	0.74^{a}	0.67^{ab}	0.38	0.42	0.43	0.41	0.54	0.57
P	NS		NS		NS		0.001		0.001		0.045		NS		NS		NS	
Irrigation																		
Daily	0.53	0.51	0.47^{a}	0.40^{ab}	0.62^{a}	0.60^{a}	0.44	0.40	0.43^{b}	0.39^{d}	0.76^{a}	0.67^{b}	0.33	0.455	0.42	0.42	0.56	0.58
Once in three days	0.49	0.59	0.36^{b}	0.46^{a}	0.62^{a}	0.60^{a}	0.45	0.47	0.50^{a}	0.42^{bc}	0.65^{b}	0.61^{b}	0.40	0.382	0.43	0.44	0.55	0.54
Once in six days	0.53	0.47	0.31^{b}	0.31^{b}	0.55^{b}	0.53^{c}	0.42	0.49	0.40^{c}	0.37^{e}	0.64^{b}	0.62^{b}	0.37	0.415	0.40	0.42	0.52	0.56
P	NS		0.001		0.008		NS		0.00		0.009		NS		NS		NS	
Provenance Mean	0.54	1.81	0.38	0.39	0.60	0.58	0.43	0.45	0.44	0.40	0.68	0.63	0.43	0.41	0.43	0.43	0.55	0.56
P	NS		NS		NS		NS		0.002		NS		0.021		NS		0.007	
SEm ±	0.060		0.051		0.040		0.033		0.014		0.0481		0.025		0.027		0.038	

S-N : Nitrogen content of Shimoga provenance, M-N : Nitrogen content of Marayoor provenance
S-P : Phosphorus content of Shimoga provenance, M-P : Phosphorus content of Marayoor provenance
S-K : Potassium content of Shimoga provenance, M-K : Potassium content of Marayoor provenance

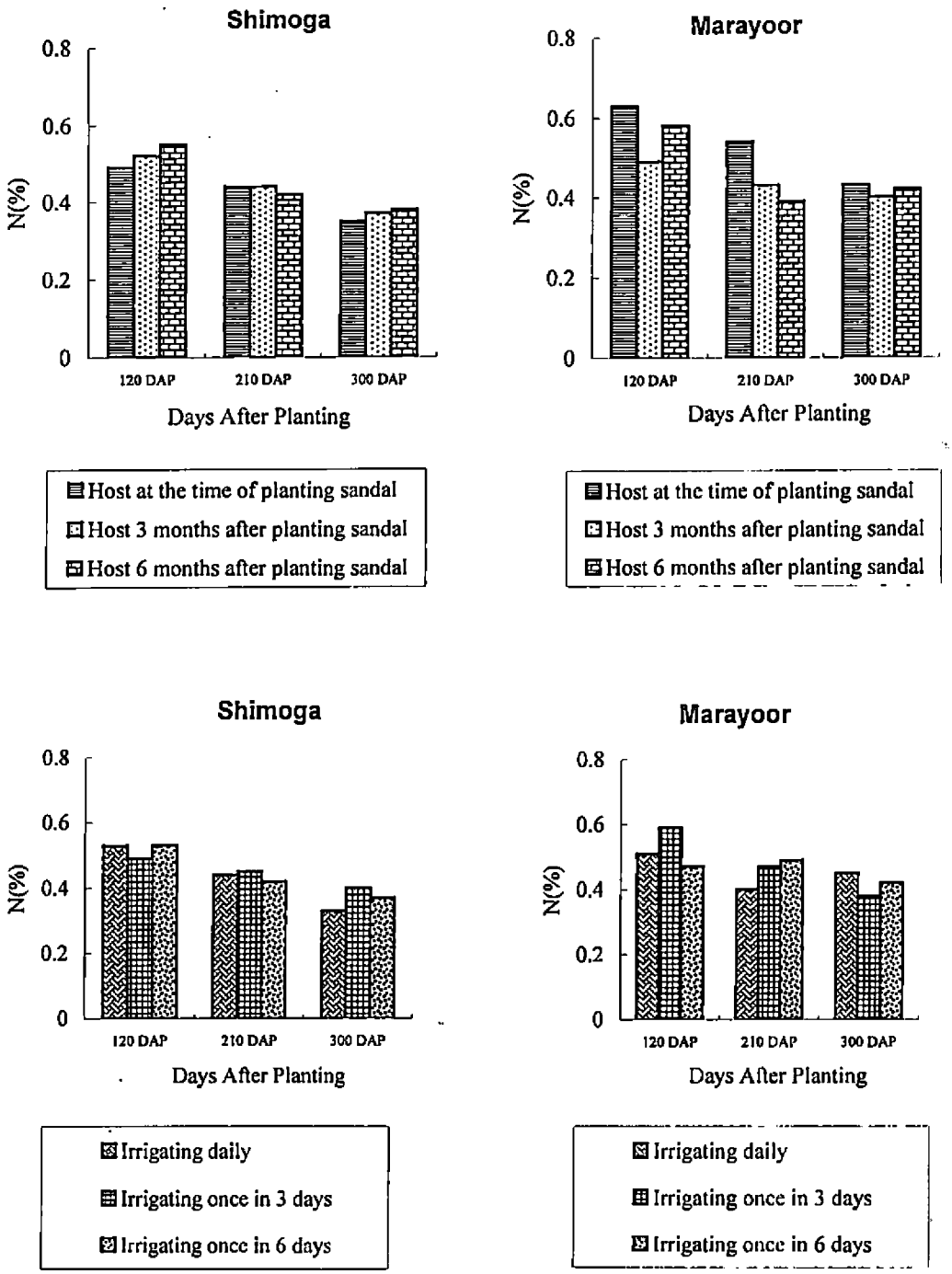


Fig. 14. Nitrogen content of sandal seedlings in Shimoga and Marayoor provenance as affected by stage of host introduction and levels of water stress

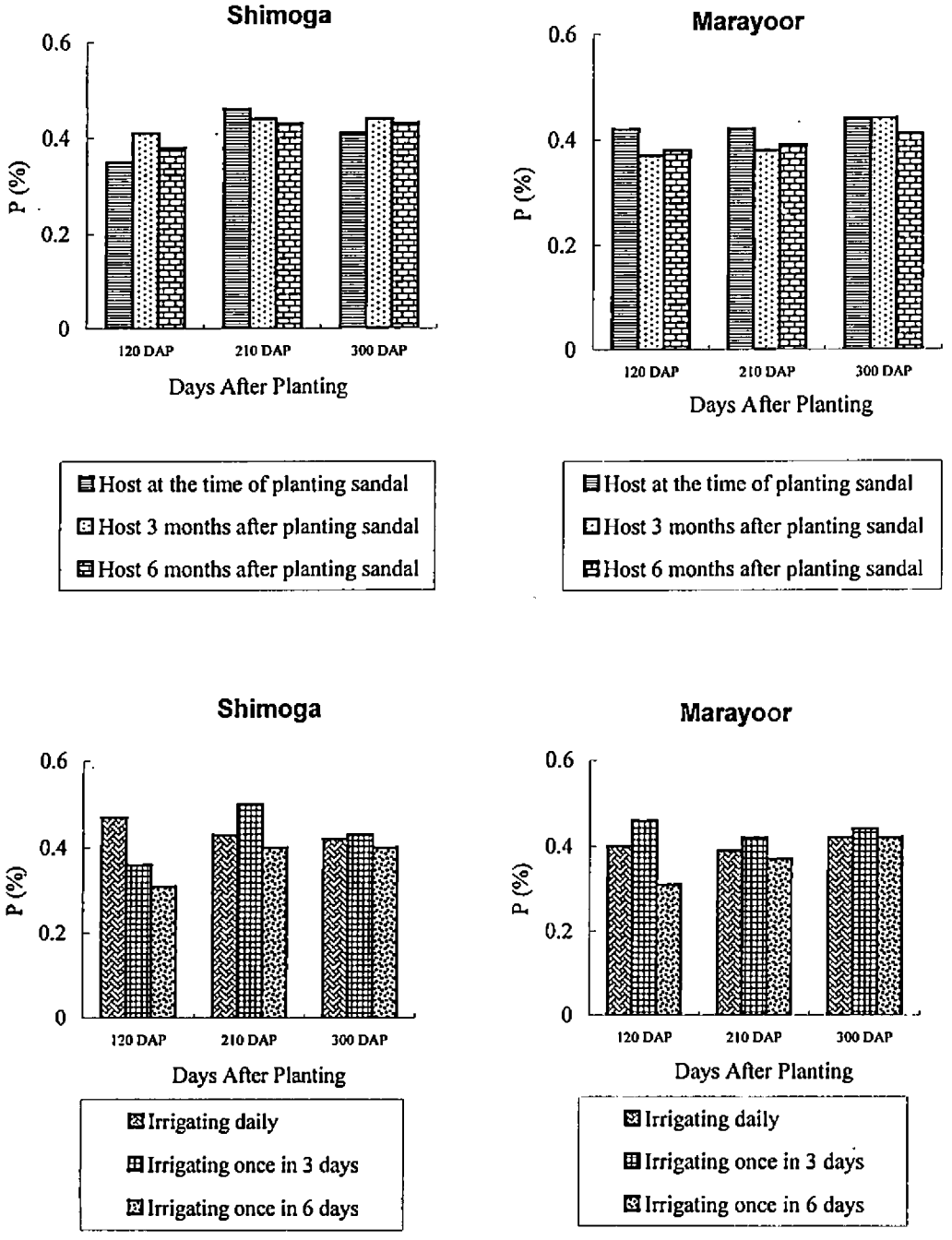


Fig. 15. Phosphorus content of sandal seedlings in Shimoga and Marayoor provenance as affected by stage of host introduction and levels of water stress

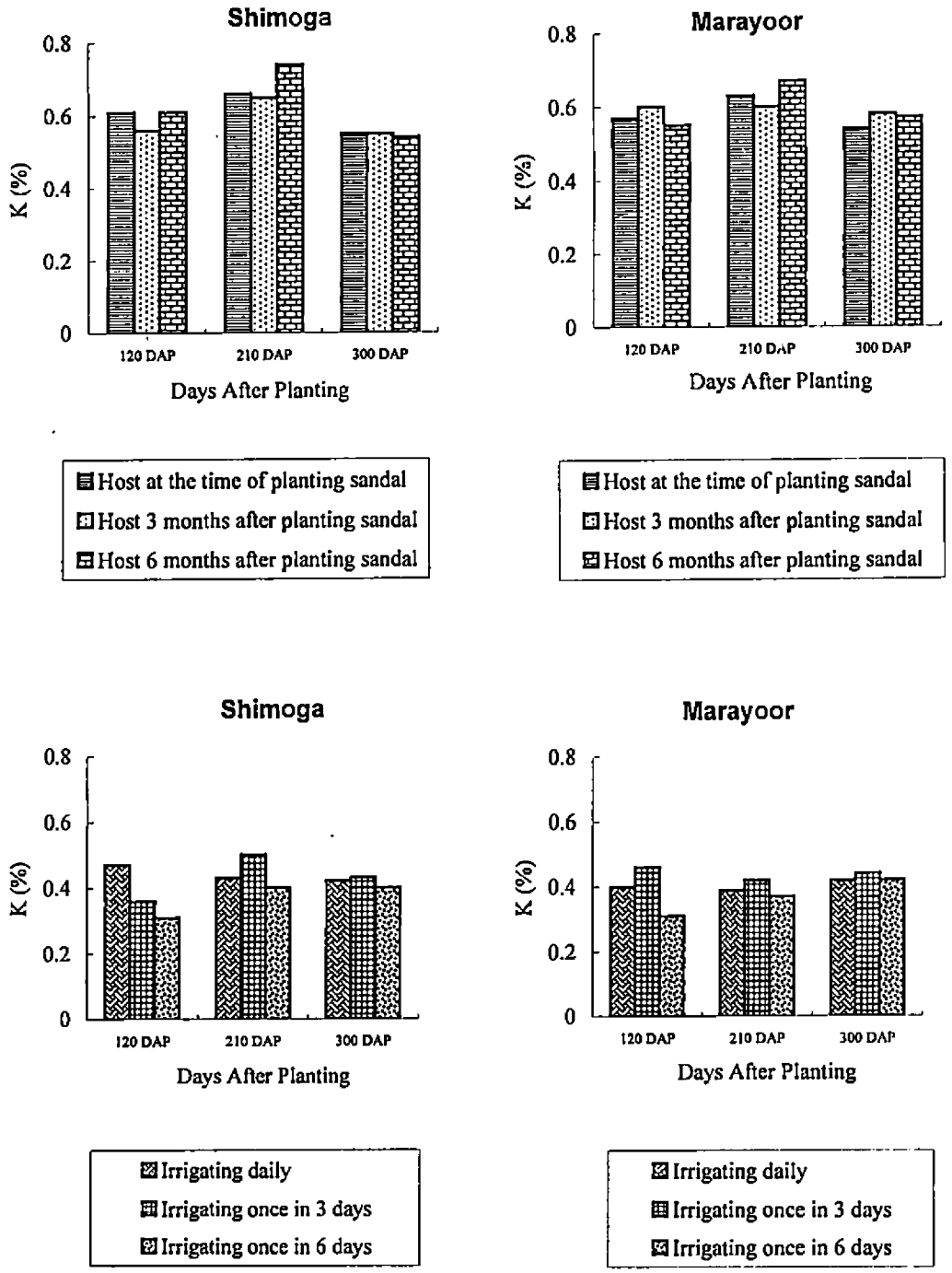


Fig. 16. Potassium content of sandal seedlings in Shimoga and Marayoor provenance as affected by stage of host introduction and levels of water stress

Table 45. Interaction effects of stage of host introduction and irrigation levels on the nitrogen content (%) of sandal seedlings

Stage of host introduction	Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean
	120 Days after planting			
At the time of planting sandal	0.50	0.48	0.49	0.49
3 months after planting sandal	0.53	0.55	0.48	0.52
6 months after planting sandal	0.53	0.61	0.54	0.56
Mean	0.52	0.55	0.50	
P (0.05)	NS			
SEm ±	0.59			
Stage of Host introduction	210 Days after planting			
At the time of planting sandal	0.40^{c}	0.52^{a}	0.55^{a}	0.49
3 months after planting sandal	0.43^{bc}	0.46^{b}	0.43^{bc}	0.44
6 months after planting sandal	0.42^{c}	0.40^{c}	0.40^{c}	0.41
Mean	0.42	0.46	0.46	
P (0.05)	0.00			
SEm ±	0.033			
Stage of Host introduction	300 Days after planting			
At the time of planting sandal	0.39	0.39	0.38	0.39
3 months after planting sandal	0.37	0.40	0.39	0.39
6 months after planting sandal	0.42	0.38	0.40	0.40
Mean	0.39	0.39	0.39	
P (0.05)	NS			
SEm ±	0.025			

Table 46. Interaction effects of provenances, hosts and irrigation levels on Nitrogen content (%) of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	0.53	0.41	0.53	0.49	0.46	0.55	0.44	0.48
3 months after planting sandal	0.58	0.49	0.49	0.54	0.49	0.61	0.47	0.52
6 months after planting sandal	0.48	0.59	0.58	0.55	0.58	0.62	0.50	0.57
Mean	0.53	0.50	0.53		0.51	0.59	0.47	
P (0.05)	NS							
SEm ±	0.035							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	0.41	0.47	0.46	0.45	0.39	0.58	0.64	0.54
3 months after planting sandal	0.48	0.47	0.39	0.45	0.39	0.45	0.46	0.43
6 months after planting sandal	0.43	0.42	0.42	0.42	0.41	0.38	0.38	0.39
Mean	0.44	0.45	0.42		0.40	0.47	0.49	
P (0.05)	NS							
SEm ±	0.019							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	0.35^{cde}	0.38^{bcde}	0.32^{e}	0.35	0.43^{bc}	0.40^{bcd}	0.45^{b}	0.43
3 months after planting sandal	0.33^{de}	0.41^{bc}	0.39^{bcde}	0.38	0.42^{bc}	0.39^{bcde}	0.40^{bcd}	0.41
6 months after planting sandal	0.33^{de}	0.40^{bcd}	0.40^{bcd}	0.38	0.52^{a}	0.36^{cde}	0.40^{bcd}	0.43
Mean	0.34	0.40	0.37		0.46	0.38	0.42	
P (0.05)	0.021							
SEm ±	0.014							

provenance when the host was introduced at the time of planting sandal. The N content at 210 DAP varied significantly due to the stage of host introduction. The seedlings of Marayoor provenance where the host was introduced at the time of planting sandal had highest N content whereas the N content, when the host was introduced at three and six months after planting sandal were on par. The levels of water stress did not show significant effect on the N content of the sandal seedlings at any of the stages of observation. The seedlings where the host was introduced three and six months after planting sandal had significantly lower N content in Marayoor provenance. In Shimoga provenance, there was no significant difference in N content due to the presence of host at any of the stages. In Shimoga provenance the N content was minimum when the host was introduced at the time of planting sandal and water stressed for six days. The N content in the seedlings of Shimoga provenance increased with the increase in water stress. However, this pattern was not observed in Marayoor provenance. In Marayoor the maximum N content was observed when they were irrigated daily and host introduced six months after planting sandal (Table 44).

The interaction effects of stage of host introduction and irrigation levels on the nitrogen content of sandal seedlings were significant only at 210 DAP (Table 45). At 210 DAP the seedlings watered once in six days and with hosts from the time of planting sandal had highest N content.

Interactions of sandal provenances, stage of host introduction and levels of water stress were highly significant at 300 DAP (Table 46). The interactions were more prominent in Marayoor provenance. At 300 DAP, where the host was introduced six months after planting sandal and watered daily had high N content whereas the lowest N content was observed in Shimoga provenance where the host was introduced at the time of planting sandal and watered once in six days.

4.3.2 Phosphorus

The P content of sandal seedlings at 120, 210 and 300 DAP are shown in Table 44, 47 and 48 and Fig. 15. In both the provenances, P content was significantly higher when the host was introduced at the time of planting sandal. The P content of

Table 47. Interaction effects of stage of host introduction and irrigation levels on the phosphorus content (%) of sandal seedlings

Stage of host introduction	Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean
	120 Days after planting			
At the time of planting sandal	0.51[a]	0.33[cd]	0.31[d]	0.38
3 months after planting sandal	0.42[b]	0.45[b]	0.30[d]	0.39
6 months after planting sandal	0.37[c]	0.45[b]	0.33[cd]	0.38
Mean	0.43	0.41	0.31	
P (0.05)	0.01			
SEm ±	0.051			
Stage of Host introduction	210 Days after planting			
At the time of planting sandal	0.44[b]	0.50[a]	0.38[cd]	0.44
3 months after planting sandal	0.36[d]	0.45[b]	0.41[bc]	0.41
6 months after planting sandal	0.43[c]	0.42[c]	0.38[cd]	0.41
Mean	0.41	0.46	0.39	
P (0.05)	0.00			
SEm ±	0.014			
Stage of Host introduction	300 Days after planting			
At the time of planting sandal	0.41	0.44	0.42	0.42
3 months after planting sandal	0.46	0.46	0.40	0.44
6 months after planting sandal	0.41	0.42	0.43	0.42
Mean	0.43	0.44	0.42	
P (0.05)	NS			
SEm ±	0.027			

Table 48. Interaction effects of provenances, hosts and irrigation levels on Phosphorus content (%) of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	0.55	0.23	0.28	0.35	0.49	0.43	0.35	0.42
3 months after planting sandal	0.47	0.44	0.33	0.41	0.38	0.46	0.28	0.37
6 months after planting sandal	0.39	0.41	0.34	0.38	0.35	0.49	0.31	0.38
Mean	0.47	0.36	0.32		0.41	0.46	0.31	
P (0.05)	NS							
SEm ±	0.030							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	0.49	0.51	0.38	0.46	0.39	0.50	0.38	0.42
3 months after planting sandal	0.37	0.50	0.45	0.44	0.36	0.40	0.37	0.38
6 months after planting sandal	0.44	0.48	0.38	0.43	0.42	0.37	0.38	0.39
Mean	0.43	0.50	0.42		0.39	0.42	0.38	
P (0.05)	NS							
SEm ±	0.008							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	0.38	0.44	0.40		0.44	0.45	0.44	0.44
3 months after planting sandal	0.48	0.46	0.38		0.45	0.46	0.42	0.44
6 months after planting sandal	0.45	0.41	0.43		0.38	0.43	0.44	0.42
Mean	0.44	0.44	0.40		0.42	0.45	0.44	
P (0.05)	NS							
SEm ±	0.016							

Table 49. Interaction effects of stage of host introduction and irrigation levels on the potassium content (%) of sandal seedlings

Stage of host introduction	Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean
	120 Days after planting			
At the time of planting sandal	0.67[a]	0.65[a]	0.46[d]	0.59
3 months after planting sandal	0.55[c]	0.61[ab]	0.58[b]	0.58
6 months after planting sandal	0.61[ab]	0.57[c]	0.57[c]	0.58
Mean	0.61	0.61	0.54	
P (0.05)	0.00			
SEm ±	0.04			
Stage of Host introduction	210 Days after planting			
At the time of planting sandal	0.74	0.63	0.57	0.65
3 months after planting sandal	0.71	0.59	0.59	0.63
6 months after planting sandal	0.70	0.68	0.73	0.70
Mean	0.72	0.63	0.63	
P (0.05)	NS			
SEm ±	0.048			
Stage of Host introduction	300 Days after planting			
At the time of planting sandal	0.57	0.57	0.50	0.55
3 months after planting sandal	0.59	0.52	0.58	0.56
6 months after planting sandal	0.56	0.57	0.54	0.56
Mean	0.57	0.55	0.54	
P (0.05)	NS			
SEm ±	0.038			

Table 50. Interaction effects of provenances, hosts and irrigation levels on Potassium content (%) of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	0.66	0.65	0.42	0.57	0.67	0.65	0.51	0.61
3 months after planting sandal	0.58	0.61	0.60	0.60	0.52	0.61	0.56	0.56
6 months after planting sandal	0.57	0.54	0.56	0.56	0.66	0.61	0.58	0.62
Mean	0.60	0.60	0.53		0.62	0.63	0.55	
P (0.05)	NS							
SEm ±	0.023							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	0.78	0.63	0.59	0.67	0.70	0.63	0.56	0.63
3 months after planting sandal	0.79	0.59	0.59	0.66	0.63	0.59	0.60	0.61
6 months after planting sandal	0.73	0.73	0.76	0.75	0.68	0.62	0.70	0.67
Mean.	0.77	0.65	0.68		0.67	0.61	0.62	
P (0.05)	NS							
SEm ±	0.028							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	0.61^{ab}	0.56^{ab}	0.49^{b}	0.55	0.53^{b}	0.59^{ab}	0.51^{b}	0.54
3 months after planting sandal	0.50^{b}	0.55^{b}	0.59^{ab}	0.55	0.69^{a}	0.48^{b}	0.56^{ab}	0.58
6 months after planting sandal	0.59^{ab}	0.56^{ab}	0.49^{b}	0.55	0.53^{b}	0.58^{ab}	0.60^{ab}	0.57
Mean	0.57	0.56	0.54		0.58	0.55	0.56	
P (0.05)	0.007							
SEm ±	0.022							

sandal seedlings at 210 DAP varied significantly due to the stage of host introduction. Comparatively the seedlings of Shimoga provenance were having a higher P content. The introduction of host at the time of planting sandal increased the P content of the sandal seedlings in both the provenances. In Marayoor provenance P content decreased significantly at 300 DAP when the plants were water stressed for three days. The levels of water stress showed significant influence on the P content of the sandal seedlings at 120 and 210 DAP. At 120 DAP the seedlings of Shimoga and Marayoor provenance, which were irrigated daily and once in three days respectively, had higher N content. The seedlings of Shimoga provenance that were watered once in three days had highest P content. The seedlings of Marayoor provenance, which were watered once in six days, had the lowest P content (Table 44).

The interaction effects of stage of host introduction and irrigation levels on the phosphorus content of sandal seedlings were significant only at 120 and 210 DAP. At 120 DAP the seedlings watered daily and host at the time of planting sandal had highest P content whereas to 210 DAP the seedlings watered once in three days and with host at the time of planting sandal had highest P content (Table 47).

Interaction of sandal provenances, stage of host introduction and levels of water stress on P content of the sandal seedlings were not significant at any of the stages (Table 48).

4.3.3 Potassium

The potassium content of sandal seedlings at 120, 210 and 300 DAP are shown in Table 44, 49 and 50 and Fig. 16. On the other hand K content of the seedlings were lower when the host was introduced at the time of planting or three months after planting sandal as compared to introduction of host six months after planting sandal. This difference was more prominent in Marayoor provenance. The K content of sandal seedlings at 210 DAP showed significant variation due to the stage of host introduction. The seedlings of Shimoga provenance recorded a higher K content as compared to seedlings of Marayoor provenance at all the stages of host introduction. Introduction of host plants six months after planting sandal resulted in higher K content in both the

provenances. The K content of seedlings was highest in Marayoor provenance, which was irrigated daily and host introduced three months after planting sandal. The influence of levels of water stress were significant on the K content of the sandal seedlings at 120 and 210 DAP. At 120 DAP the seedlings irrigated daily or once in three days had higher K content. The lowest K content was recorded in seedlings watered once in six days. At 210 DAP the seedlings watered daily had higher K content in Shimoga provenance (Table 44).

The interaction effects of stage of host introduction and irrigation levels on the potassium content of sandal seedlings were significant only at 120 DAP (Table 49). The seedlings watered once in 3 days and with host at the time of planting sandal had highest K content.

Interaction of sandal provenances, stage of host introduction and levels of water stress on K content of the sandal seedlings were significant only at 300 DAP (Table 50). The seedlings of Marayoor provenance where the host was introduced three months after planting sandal and watered daily had higher K content.

4.3.4 Sodium

The Na content of sandal seedlings at 120, 210 and 300 DAP are shown in Table 51, 52 and 53 and Fig. 17. The stage of host introduction or the levels of water stress did not show any significant effect on the Na content of sandal seedlings in both the provenances (Table 51).

The interaction effects of stage of host introduction and irrigation levels on the sodium content of sandal seedlings were not significant at any of the stages (Table 52).

Interaction of sandal provenances, stage of host introduction and levels of water stress on Na content of the sandal seedlings were not significant at any of the stages (120, 210 and 300 DAP) in both the provenances (Table 53).

4.3.5 Calcium

The Ca content of sandal seedlings at 120, 210 and 300 DAP are shown in Table 51, 54 and 55 and Fig. 18. The stage of host introduction had a significant effect

Table 51. Na and Ca content (%) of sandal seedlings as affected by stage of host introduction and different levels of water stress

Provenances	Days after planting											
	120 DAP				210 DAP				300 DAP			
	S - Na	M-Na	S - Ca	M - Ca	S - Na	M - Na	S - Ca	M - Ca	S - Na	M-Na	S - Ca	M - Ca
Stage of Host introduction												
At the time of planting sandal	0.07	0.08	0.89[b]	1.04[a]	0.10	0.09	1.11	1.10	0.08	0.09	1.10	1.10
3 months after planting sandal	0.07	0.09	0.95[ab]	0.95[ab]	0.09	0.08	1.06	1.12	0.08	0.08	1.09	1.14
6 months after planting sandal	0.07	0.09	1.07[a]	1.06[a]	0.09	0.09	1.07	1.09	0.09	0.09	1.11	1.17
P	NS		0.037		NS		NS		NS		NS	
Irrigation												
Daily	0.08	0.09	0.90	1.05	0.09	0.09	1.04	1.05	0.08	0.08	1.12	1.13
Once in three days	0.07	0.08[b]	1.03	0.99	0.10	0.08	1.11	1.13	0.08	0.08	1.08	1.14
Once in six days	0.07	0.09[a]	0.99	1.01	0.10	0.09	1.10	1.13	0.09[c]	0.09	1.11	1.11
P	NS		NS		NS		NS		NS		NS	
Provenance Mean	0.07	0.09	0.97	1.02	0.10	0.09	1.08	1.10	0.08	0.08	1.10	1.13
P	NS		0.018		NS		NS		NS		NS	
SEm ±	0.007		0.073		0.006		0.069		0.011		0.057	

S-Na : Sodium content of Shimoga provenance, M-Na : Sodium content of Marayoor provenance
S-Ca : Calcium content of Shimoga provenance, M-Ca : Calcium content of Marayoor provenance

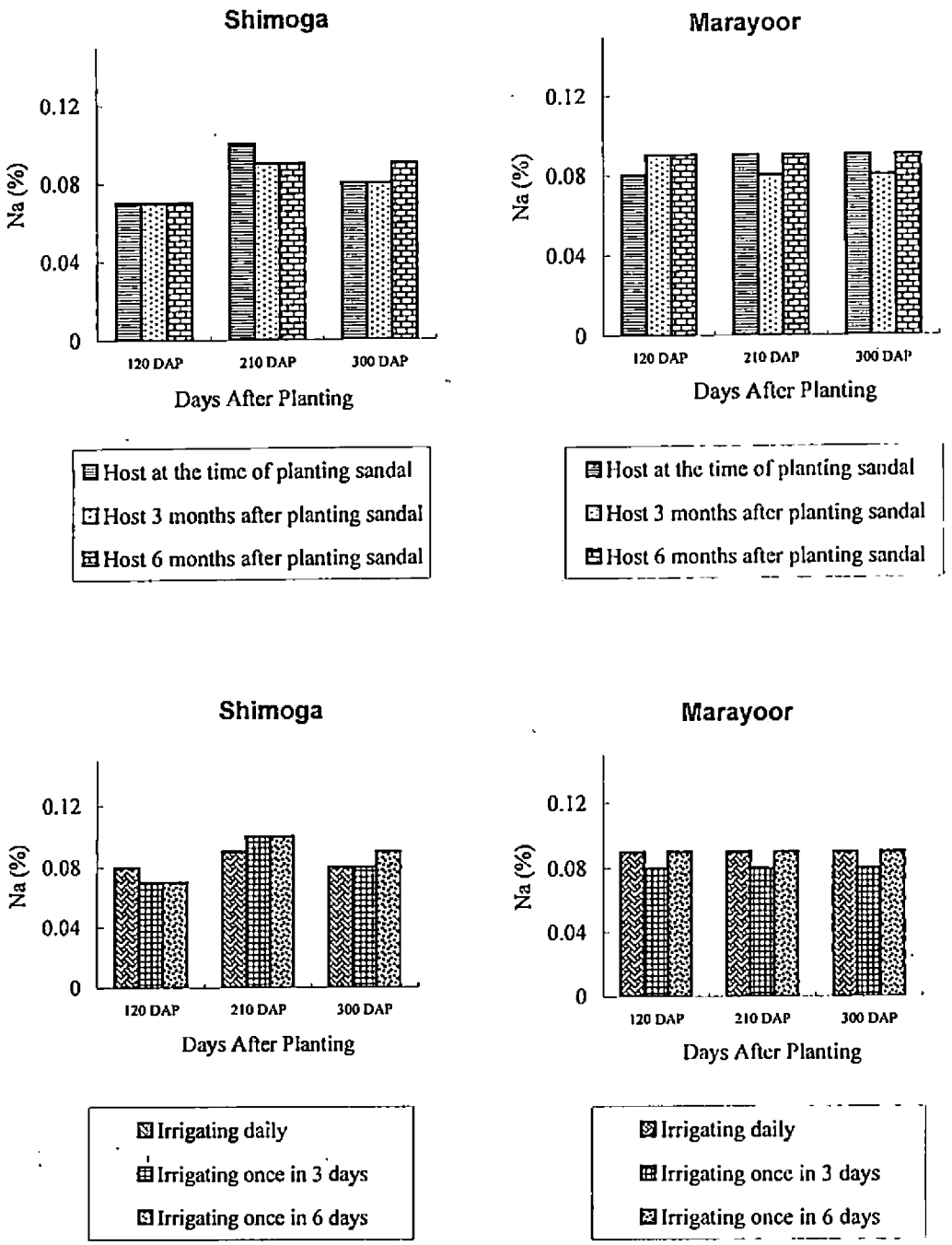


Fig. 17. Sodium content of sandal seedlings in Shimoga and Marayoor provenance as affected by stage of host introduction and levels of water stress

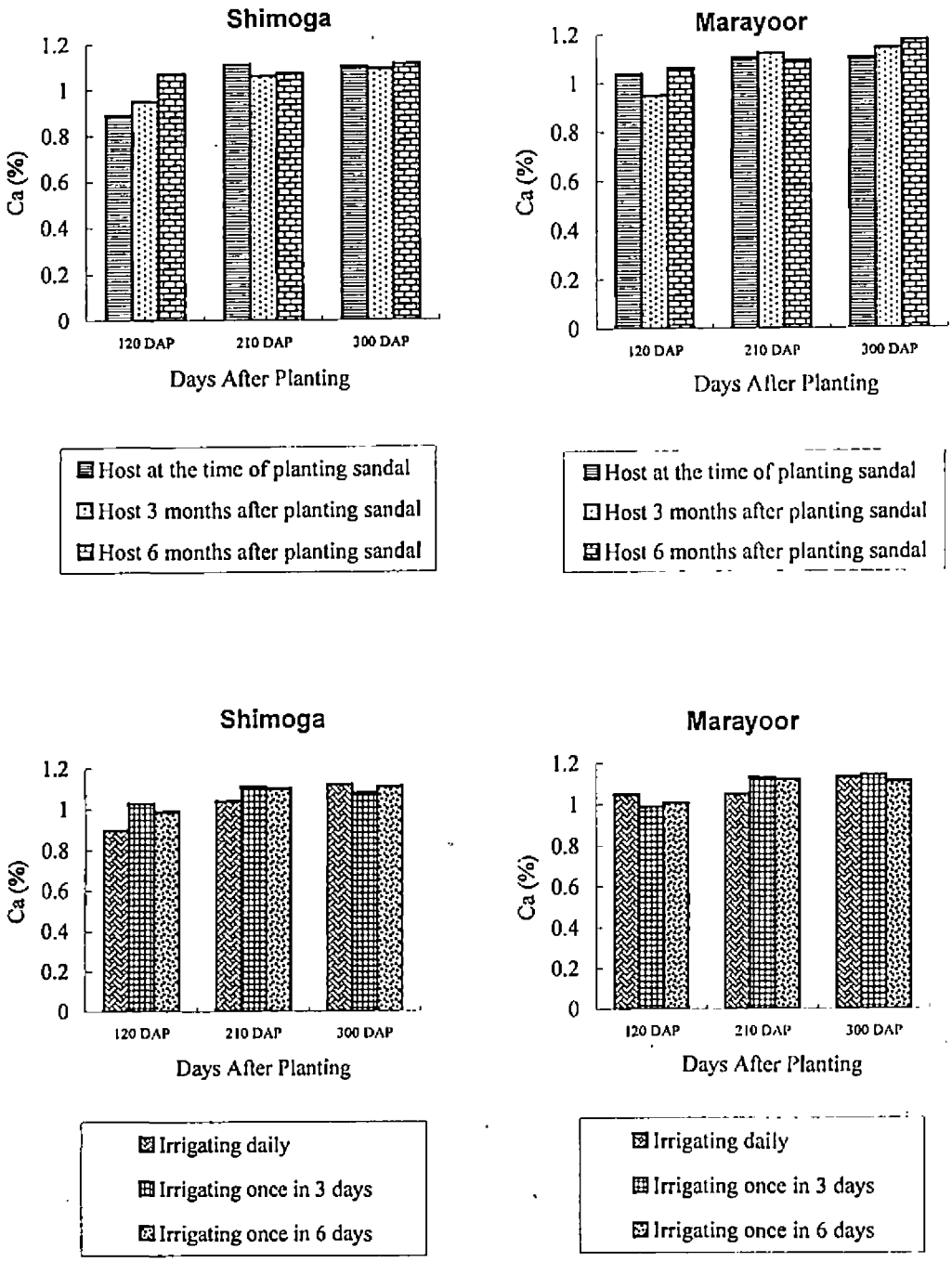


Fig. 18. Calcium content of sandal seedlings in Shimoga and Marayoor provenance as affected by stage of host introduction and levels of water stress

Table 52. Interaction effects of stage of host introduction and irrigation levels on the sodium content (%) of sandal seedlings

Stage of host introduction	Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean
	120 Days after planting			
At the time of planting sandal	0.09	0.07	0.08	0.08
3 months after planting sandal	0.08	0.08	0.08	0.08
6 months after planting sandal	0.09	0.08	0.09	0.09
Mean	0.09	0.08	0.08	
P (0.05)	NS			
SEm ±	0.007			
Stage of Host introduction	210 Days after planting			
At the time of planting sandal	0.09	0.09	0.09	0.09
3 months after planting sandal	0.09	0.08	0.08	0.08
6 months after planting sandal	0.08	0.08	0.08	0.08
Mean	0.09	0.08	0.08	
P (0.05)	NS			
SEm ±	0.006			
Stage of Host introduction	300 Days after planting			
At the time of planting sandal	0.10	0.08	0.09	0.09
3 months after planting sandal	0.08	0.09	0.09	0.09
6 months after planting sandal	0.09	0.09	0.10	0.09
Mean	0.09	0.09	0.09	
P (0.05)	NS			
SEm ±	0.01			

Table 53. Interaction effects of provenances, hosts and irrigation levels on Sodium content (%) of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	0.08	0.08	0.07	0.08	0.09	0.08	0.09	0.09
3 months after planting sandal	0.08	0.07	0.08	0.08	0.09	0.09	0.09	0.09
6 months after planting sandal	0.09	0.07	0.07	0.08	0.10	0.09	0.10	0.10
Mean	0.09	0.07	0.07		0.09	0.09	0.09	
P (0.05)	NS							
SEm ±	0.004							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.09
3 months after planting sandal	0.10	0.09	0.09	0.09	0.09	0.08	0.09	0.09
6 months after planting sandal	0.09	0.10	0.10	0.10	0.09	0.09	0.09	0.09
Mean	0.10	0.10	0.10		0.09	0.09	0.09	
P (0.05)	NS							
SEm ±	0.004							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	0.10	0.07	0.09	0.09	0.10	0.01	0.09	0.10
3 months after planting sandal	0.07	0.09	0.09	0.09	0.08	0.09	0.10	0.09
6 months after planting sandal	0.09	0.09	0.10	0.09	0.09	0.08	0.10	0.09
Mean	0.09	0.09	0.09		0.09	0.09	0.10	
P (0.05)	NS							
SEm ±	0.006							

Table 54. Interaction effects of stage of host introduction and irrigation levels on the calcium content (%) of sandal seedlings

Stage of host introduction	Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean
	120 Days after planting			
At the time of planting sandal	0.96	0.95	0.99	0.97
3 months after planting sandal	0.96	1.01	0.88	0.95
6 months after planting sandal	1.01	1.04	1.13	1.06
Mean	0.98	1.00	1.00	
P (0.05)	NS			
SEm ±	0.073			
Stage of Host introduction	210 Days after planting			
At the time of planting sandal	1.08	1.18	1.05	1.10
3 months after planting sandal	1.03	1.10	1.14	1.09
6 months after planting sandal	1.03	1.07	1.14	1.08
Mean	1.05	1.12	1.11	
P (0.05)	NS			
SEm ±	0.069			
Stage of Host introduction	300 Days after planting			
At the time of planting sandal	1.17	1.08	1.07	1.11
3 months after planting sandal	1.14	1.08	1.13	1.12
6 months after planting sandal	1.07	1.18	1.13	1.13
Mean	1.13	1.11	1.11	
P (0.05)	NS			
SEm ±	0.057			

Table 55. Interaction effects of provenances, hosts and irrigation levels on Calcium content (%) of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	0.87^{cde}	0.98^{abcde}	0.84^{de}	0.90	1.05^{abcde}	0.93^{abcde}	1.15^{ab}	1.04
3 months after planting sandal	0.95^{abcde}	0.94^{abcde}	0.97^{abcde}	0.95	0.98^{abcde}	1.09^{abcd}	0.79^{e}	0.95
6 months after planting sandal	0.90^{bcde}	1.13^{ab}	1.17^{a}	1.07	1.13^{ab}	0.95^{abcde}	1.10^{abc}	1.06
Mean	0.91	1.01	0.99		1.05	0.99	1.01	
P (0.05)	0.018							
SEm ±	0.042							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	1.07	1.17	1.10	1.11	1.09	1.21	1.01	1.10
3 months after planting sandal	1.01	1.03	1.14	1.06	1.05	1.18	1.14	1.12
6 months after planting sandal	1.03	1.14	1.05	1.07	1.03	1.01	1.24	1.09
Mean	1.04	1.11	1.10		1.13	1.13	1.13	
P (0.05)	NS							
SEm ±	0.040							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	1.18	1.07	1.08	1.11	1.17	1.09	1.06	1.11
3 months after planting sandal	1.12	0.99	1.17	1.09	1.17	1.17	1.10	1.14
6 months after planting sandal	1.08	1.19	1.08	1.11	1.06	1.17	1.19	1.14
Mean	1.12	1.08	1.11		1.12	1.13	1.12	
P (0.05)	NS							
SEm ±	0.033							

Table 55. Interaction effects of provenances, hosts and irrigation levels on Calcium content (%) of sandal seedlings

Provenances	Shimoga				Marayoor			
	Irrigation				Irrigation			
	Daily	Once in 3 days	Once in 6 days	Mean	Daily	Once in 3 days	Once in 6 days	Mean
Stage of host introduction	120 Days after planting				120 Days after planting			
At the time of planting sandal	0.87^{cde}	0.98^{abcde}	0.84^{de}	0.90	1.05^{abcde}	0.93^{abcde}	1.15^{ab}	1.04
3 months after planting sandal	0.95^{abcde}	0.94^{abcde}	0.97^{abcde}	0.95	0.98^{abcde}	1.09^{abcd}	0.79^{e}	0.95
6 months after planting sandal	0.90^{bcde}	1.13^{ab}	1.17^{a}	1.07	1.13^{ab}	0.95^{abcde}	1.10^{abc}	1.06
Mean	0.91	1.01	0.99		1.05	0.99	1.01	
P (0.05)	0.018							
SEm ±	0.042							
Stage of Host introduction	210 Days after planting				210 Days after planting			
At the time of planting sandal	1.07	1.17	1.10	1.11	1.09	1.21	1.01	1.10
3 months after planting sandal	1.01	1.03	1.14	1.06	1.05	1.18	1.14	1.12
6 months after planting sandal	1.03	1.14	1.05	1.07	1.03	1.01	1.24	1.09
Mean	1.04	1.11	1.10		1.13	1.13	1.13	
P (0.05)	NS							
SEm ±	0.040							
Stage of Host introduction	300 Days after planting				300 Days after planting			
At the time of planting sandal	1.18	1.07	1.08	1.11	1.17	1.09	1.06	1.11
3 months after planting sandal	1.12	0.99	1.17	1.09	1.17	1.17	1.10	1.14
6 months after planting sandal	1.08	1.19	1.08	1.11	1.06	1.17	1.19	1.14
Mean	1.12	1.08	1.11		1.12	1.13	1.12	
P (0.05)	NS							
SEm ±	0.033							

Table 56. Height (cm) of *C. cajan* seedlings as affected by introducing with *S. album* at various stages and in different levels of water stress

Provenances	Days after planting					
	120 DAP		210 DAP		300 DAP	
	Shimoga	Marayoor	Shimoga	Marayoor	Shimoga	Marayoor
Stage of Host introduction						
At the time of planting sandal	51.49[b]	51.68[a]	77.61[a]	74.97[ab]	73.30[a]	73.48[a]
3 months after planting sandal	HNI	HNI	49.67[b]	53.42[b]	72.24[a]	73.09[a]
6 months after planting sandal	HNI	HNI	HNI	HNI	73.29[a]	73.51[a]
P	--------		0.00		NS	
Irrigation						
Daily	53.50	51.60	65.60	64.23	91.27[a]	92.15[a]
Once in three days	51.37	51.33	65.80	63.58	75.04[b]	74.31[b]
Once in six days	49.60	51.90	59.52	64.77	52.52[c]	53.62[c]
P	NS	NS	NS	NS	0.00	0.00
Provenance Mean	51.49	51.63	63.64	64.19	72.94	13.36
P	NS		NS	NS	NS	NS
SEm ±	------		50.08		6.19	

HNI – Host was not introduced at this stage

Table 57. Co-relation between shoot height of sandal and red gram seedlings at various stages

	Shimoga	Marayoor
120 DAP	-0.522	-0.464
210 DAP	-0.018	-0.216
300 DAP	0.275	-0.172

Table 58. Root length (cm) of *C. cajan* seedlings as affected by introducing with *S. album* at various stages and in different levels of water stress.

Provenances	Days after planting					
	120 DAP		210 DAP		300 DAP	
	Shimoga	Marayoor	Shimoga	Marayoor	Shimoga	Marayoor
Stage of Host introduction						
At the time of planting sandal	17.72^{b}	18.22^{a}	25.89^{a}	26.36^{a}	25.00^{de}	24.82^{e}
3 months after planting sandal	HNI	HNI	21.23^{b}	20.77^{b}	26.08^{bc}	25.92^{cd}
6 months after planting sandal	HNI	HNI	HNI	HNI	27.58^{a}	26.92^{ab}
P	--------		0.00	0.00	0.00	0.00
Irrigation						
Daily	16.80^{b}	17.67^{b}	22.05^{c}	22.40^{bc}	20.34^{d}	19.86^{d}
Once in three days	16.83^{b}	18.47^{ab}	23.80^{ab}	23.75^{ab}	26.44^{b}	25.32^{c}
Once in six days	19.53^{a}	18.53^{ab}	24.83^{a}	24.53^{a}	31.87^{a}	32.49^{a}
P	0.015	0.015	0.0003	0.0003	0.00	0.00
Provenance Mean	17.72	18.22	23.56	23.56	26.21	25.88
P	0.081	0.081	NS	NS	NS	NS
SEm ±	---------		1.58	1.58	0.97	0.97

HNI – Host was not introduced at this stage

Table 59. Co-relation between root length of sandal and red gram seedlings at various stages

Provenances	Shimoga	Marayoor
120 DAP	-0.130	0.514
210 DAP	0.412	0.248
300 DAP	-0.024	-0.092

red gram seedlings when they were introduced with sandal seedlings. The seedlings of Shimoga provenance where the host was introduced six months after planting sandal had highest root length whereas seedlings of Marayoor provenance where the host was introduced at the time of planting sandal showed lowest root length. As the levels of water stress increased, there was an increase in the root length of the red gram seedlings when introduced in both the provenances. At both 210 and 300 DAP the red gram seedlings introduced in both the provenances, which were irrigated once in six days showed an increased root length.

The root length of the host (red gram) when correlated with seedlings of sandal revealed that at 300 DAP the root length of both sandal and red gram were negatively co-related at 300 DAP in both the provenances. However at 120 DAP the seedlings of Shimoga provenance showed a negative co-relation with the host (Table. 59).

4.5 PHYSIOLOGICAL PARAMETERS OF HOST (RED GRAM)

4.5.1 Pre-dawn water potential

The pre-dawn water potential of red gram seedlings when grown with sandal as a host is given in Table 60 and the comparison with sandal is in Figs 19 and 20. At 120 and 210 DAP the red gram seedlings grown as host with sandal seedlings of Shimoga provenance showed lower water potential as compared to red gram seedlings grown with Marayoor provenance. At 210 DAP there was a reverse trend where red gram seedlings showed a lower water potential when grown with Marayoor provenance.

The levels of water stress affected the water potential of the red gram seedlings at all the stages. As the levels of water stress increased there was a decrease in the water potential of the red gram seedlings and was more pronounced in the seedlings grown with Marayoor provenance.

The water potential of the host (red gram) was positively correlated with that of sandal, except in Shimoga provenances at 120 DAP (Table 61).

Table 60. Pre-dawn water potential (MPa) of *C. cajan* seedlings as affected by introducing with *S. album* at various stages and with different levels of water stress

Provenances	Days after planting					
	120		210		300	
	Shimoga	Marayoor	Shimoga	Marayoor	Shimoga	Marayoor
Stage of Host introduction						
At the time of planting sandal	-0.56[a]	-0.51[b]	-1.40[b]	-1.52[a]	-1.17[b]	-1.29[a]
3 months after planting sandal	HNI	HNI	-1.10[c]	-1.36[b]	-1.01[c]	-1.08[c]
6 months after planting sandal	HNI	HNI	HNI	HNI	-0.65[e]	-0.75[d]
P	-----		0.00		0.00	
Irrigation						
Daily	-0.37[c]	-0.36[c]	-0.90[d]	-0.96[d]	-0.79[d]	-0.84[d]
Once in three days	-0.53[ab]	-0.61[ab]	-1.10[c]	-1.51[b]	-0.93[c]	-0.98[c]
Once in six days	-0.62[ab]	-0.70[a]	-1.77[a]	-1.84[a]	-1.10[b]	-1.31[a]
P	0.00		0.00		0.00	
Provenance Mean	-0.52	-0.54	-1.25	-1.43	-0.94	-1.04
P	0.149		0.00		NS	
SEm ±	0.397		0.408		0.454	

HNI – Host was not introduced at this stage

Table 61. Co-relation between water potential of sandal and red gram seedlings at various stages

Provenances	Shimoga	Marayoor
120 DAP	0.720	-0.724
210 DAP	0.786	0.821
300 DAP	0.486	0.204

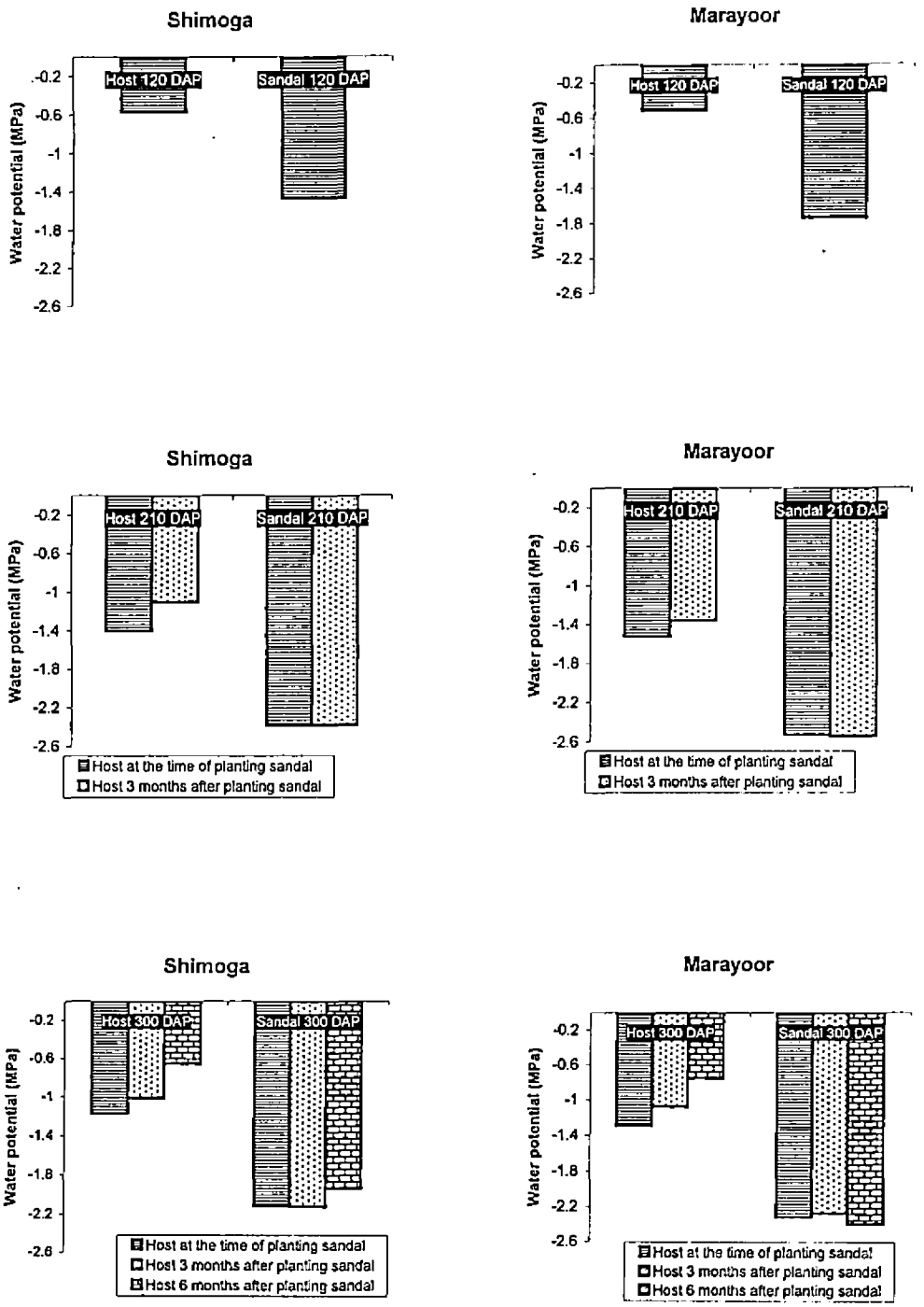


Fig. 19. Comparison of water potential of host and sandal seedlings of Shimoga and Marayoor provenances at various stages of host introduction

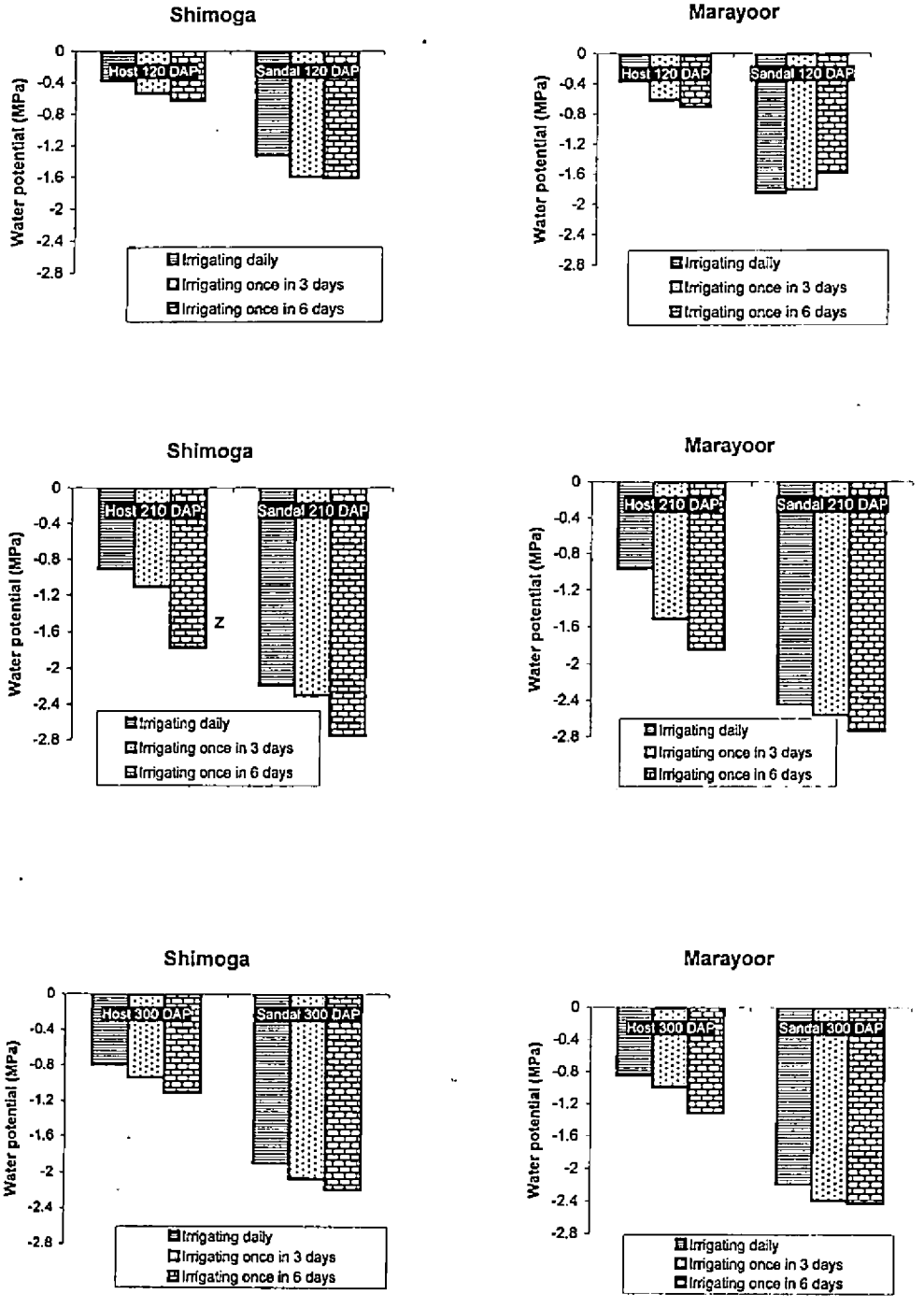


Fig. 20. Comparison of water potential of host and sandal seedlings of Shimoga and Marayoor provenances at various levels of water stress

4.5.2 Leaf diffusive resistance

The leaf diffusive resistance of red gram seedlings when grown with sandal as a host is given in Table 62 and Fig. 21. At 120 DAP the leaf diffusive resistance of red gram seedlings was high in Shimoga provenance at 0800 H, and leaf diffusive resistance of red gram seedlings was high in Marayoor provenance at 1400 H. At 210 DAP the seedlings introduced six months after planting sandal showed a higher leaf diffusive resistance in Marayoor provenance. Though not significant, the seedlings of red gram introduced in Marayoor provenance showed a higher leaf diffusive resistance at the later stages. As the levels of water stress increased, there was an increase in the leaf diffusive resistance of red gram seedlings. However, it was significant only at 1400 H at 120 DAP and at 0800 H at 210 DAP.

4.5.3 Transpiration rate

The transpiration rate of red gram seedlings when grown with sandal as a host is given in Table 63 and Fig. 22. At 210 DAP and 120 DAP at 1400 H the seedlings introduced in Shimoga provenance showed a higher transpiration rate irrespective of the stages. At 300 DAP at 0800 H the transpiration rate was almost similar pattern being followed in both the provenances, where the seedlings introduced at the time of planting sandal showed a higher transpiration rate. As there was an increase in the water stress there was a decrease in the transpiration rate of the red gram seedlings. This was more pronounced at 0800 H in the seedlings introduced in Shimoga provenance. At 1400 H the decrease in transpiration was more prominent in seedlings of Marayoor provenance.

4.5.4 Leaf temperature

The leaf temperature of red gram seedlings when grown with sandal as a host is given in Table 64. At all the stages (120, 210 and 300 DAP) the seedlings in Marayoor provenance (at 0800 H) showed higher leaf temperature as compared to the host seedlings grown with Shimoga provenance of sandal, irrespective of the stages in which they were introduced.

Table 62. Leaf Diffusive Resistance (s cm^{-1}) in *C. cajan* seedlings as affected by introducing with *S. album* at various stages and in different levels of water stress

Provenances	Days after planting											
	120 DAP				210 DAP				300 DAP			
	Shimoga 0800 Hrs	Marayoor 0800 Hrs	Shimoga 1400 Hrs	Marayoor 1400 Hrs	Shimoga 0800 Hrs	Marayoor 0800 Hrs	Shimoga 1400 Hrs	Marayoor 1400 Hrs	Shimoga 0800 Hrs	Marayoor 0800 Hrs	Shimoga 1400 Hrs	Marayoor 1400 Hrs
Time of host introduction												
At the time of planting sandal	8.57^{a} (46.67)	2.55^{b} (156.86)	3.32^{b} (120.48)	10.77^{a} (37.14)	5.93 (67.45)	3.17 (126.18)	3.43 (116.61)	4.43 (90.29)	0.78 (512.82)	3.99 (100.25)	3.19 (125.39)	4.41 (90.70)
3 months after planting sandal	HNI	HNI	HNI	HNI	1.03 388.35)	10.07 (39.72)	4.31 (92.80)	5.91 (67.68)	2.20 (181.81)	2.44 (163.93)	3.38 (118.34)	3.17 (126.18)
6 months after planting sandal	HNI	HNI	HNI	HNI	HNI	HNI	HNI	HNI	1.36 (294.12)	0.83 (481.93)	3.26 (122.70)	4.60 (86.96)
P	-----				NS		NS		NS		NS	
Irrigation												
Daily	4.99 (80.16)	2.04 (196.08)	3.07^{c} (130.29)	2.10^{c} (190.48)	1.10^{b} 363.63)	2.55^{ab} (156.86)	3.45 (115.94)	2.88 (138.88)	0.84 (476.19)	1.66 (240.96)	3.04 (131.57)	3.19 (125.39)
Once in three days	9.57 (41.80)	2.77 (144.40)	3.24^{c} (123.46)	12.53^{b} (31.92)	1.62^{b} 246.91)	3.92^{ab} (102.04)	3.97 (100.76)	5.57 (71.81)	1.28 (312.5)	2.10 (190.48)	3.25 (123.08)	3.71 (107.82)
Once in six days	11.13 (35.93)	2.82 (141.84)	3.63^{c} (110.19)	17.69^{a} (22.61)	7.73^{ab} (51.75)	13.38^{a} (29.89)	4.20 (95.24)	7.07 (56.57)	2.21 (181.00)	3.51 (113.96)	3.53 (113.31)	5.27 (75.90)
P	NS		0.0004		0.038		NS		NS		NS	
Provenance Mean	8.57 (40.67)	2.55 (156.86)	3.32 (120.48)	10.77 (37.14)	3.48 114.94)	6.62 (60.42)	4.84 (82.64)	5.17 (77.37)	1.45 (275.86)	2.42 (165.28)	3.28 (111.11)	4.06 (98.52)
P	-----				0.034		NS		NS		0.017	
SEm ±	3.073		1.446		4.92		1.331		0.715		1.096	

Values in parentheses are stomatal conductance in m mol m^{-2} s^{-1}

HNI – Host was not introduced at this stage

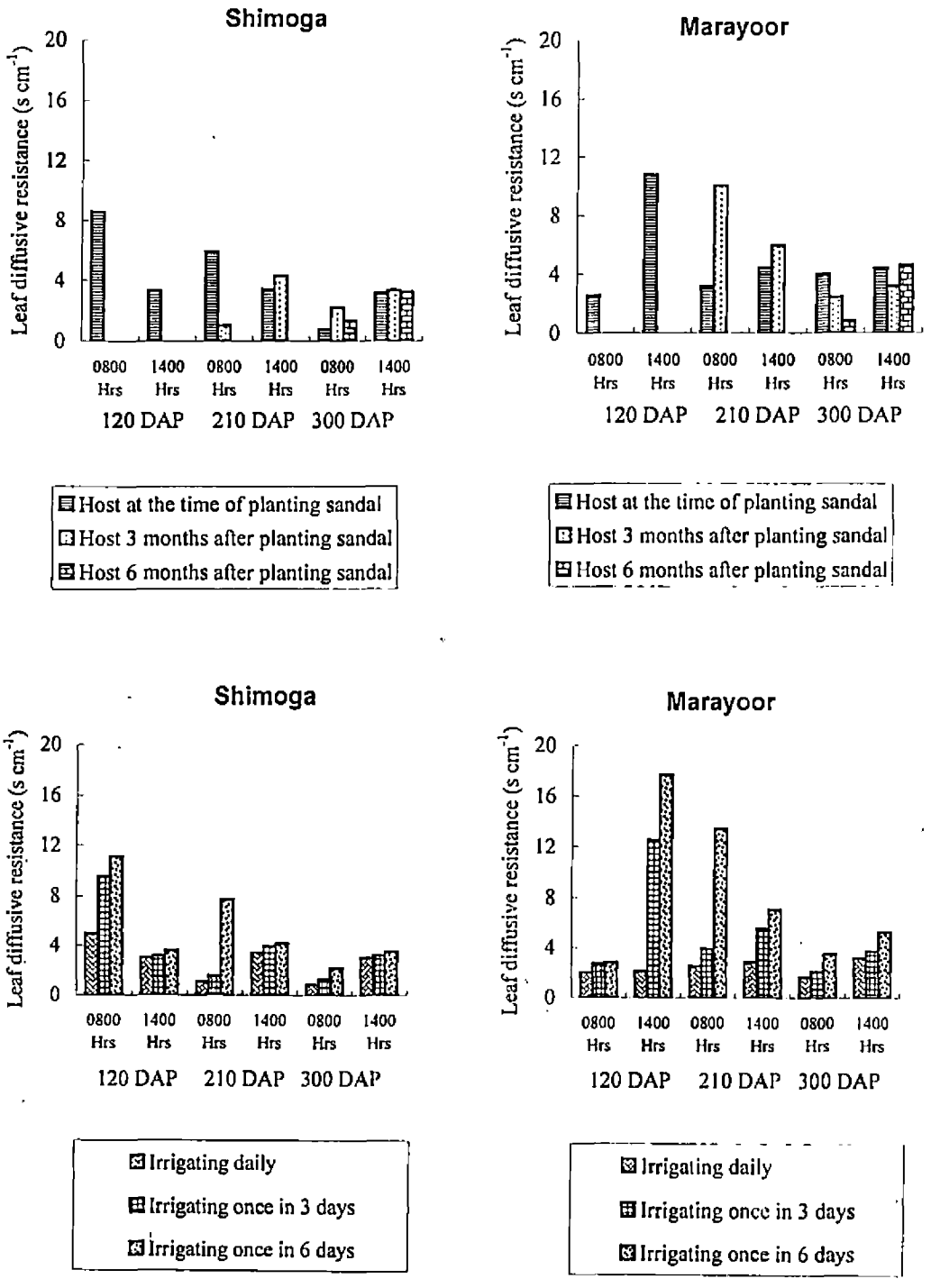


Fig. 21. Leaf diffusive resistance of host seedlings as affected by stage of its introduction with sandal in Shimoga and Marayoor provenance and at various levels of water stress

Table 63. Transpiration (µg H_2O cm^{-2} s^{-1}) in *C. cajan* seedlings as affected by introducing with *S. album* at various stages and in different levels of water stress

Provenances	Days after planting											
	120 DAP				210 DAP				300 DAP			
	S 0800 Hrs	M 0800 Hrs	S 1400 Hrs	M 1400 Hrs	S 0800 Hrs	M 0800 Hrs	S 1400 Hrs	M 1400 Hrs	S 0800 Hrs	M 0800 Hrs	S 1400 Hrs	M 1400 Hrs
Time of host introduction												
At the time of planting sandal	1.23^{b}	2.36^{a}	9.00^{a}	5.47^{b}	4.59	3.32	4.91^{a}	3.44^{b}	6.86^{a}	3.95^{c}	4.72	3.66
3 months after planting sandal	HNI	HNI	HNI	HNI	4.33	2.68	3.08^{b}	3.23^{b}	4.35^{bc}	5.30^{b}	4.96	4.62
6 months after planting sandal	HNI	HNI	HNI	HNI	HNI	HNI	HNI	HNI	4.37^{bc}	7.50^{a}	5.23	4.41
P	-----		-----		NS		0.0005		0.036		NS	
Irrigation												
Daily	1.90^{bc}	3.24^{ab}	9.69^{b}	12.12^{a}	7.45^{a}	2.71^{d}	6.23^{c}	4.98^{b}	6.86^{a}	7.64^{a}	5.56^{a}	5.36^{a}
Once in three days	1.18^{c}	3.44^{a}	9.04^{b}	2.57^{c}	5.85^{b}	4.37^{c}	3.53^{a}	3.80^{c}	4.76^{b}	4.38^{b}	6.12^{a}	4.89^{a}
Once in six days	0.60^{c}	0.41^{c}	8.29^{b}	1.71^{c}	0.08^{c}	1.92^{d}	2.22^{d}	1.23^{e}	3.97^{b}	4.71^{b}	3.21^{b}	4.89^{a}
P	0.00		0.00		0.00		0.00		0.00		0.00	
Provenance Mean	1.22	2.36	9.00	5.47	4.46	3.00	3.99	3.34	5.20	5.58	4.97	4.23
P	NS		0.00		0.00		0.00		0.002		NS	
SEm ±	0.473		0.573		0.529		0.443		0.710		0.715	

S – Shimoga provenance
M – Marayoor provenance
HNI – Host was not introduced at this stage

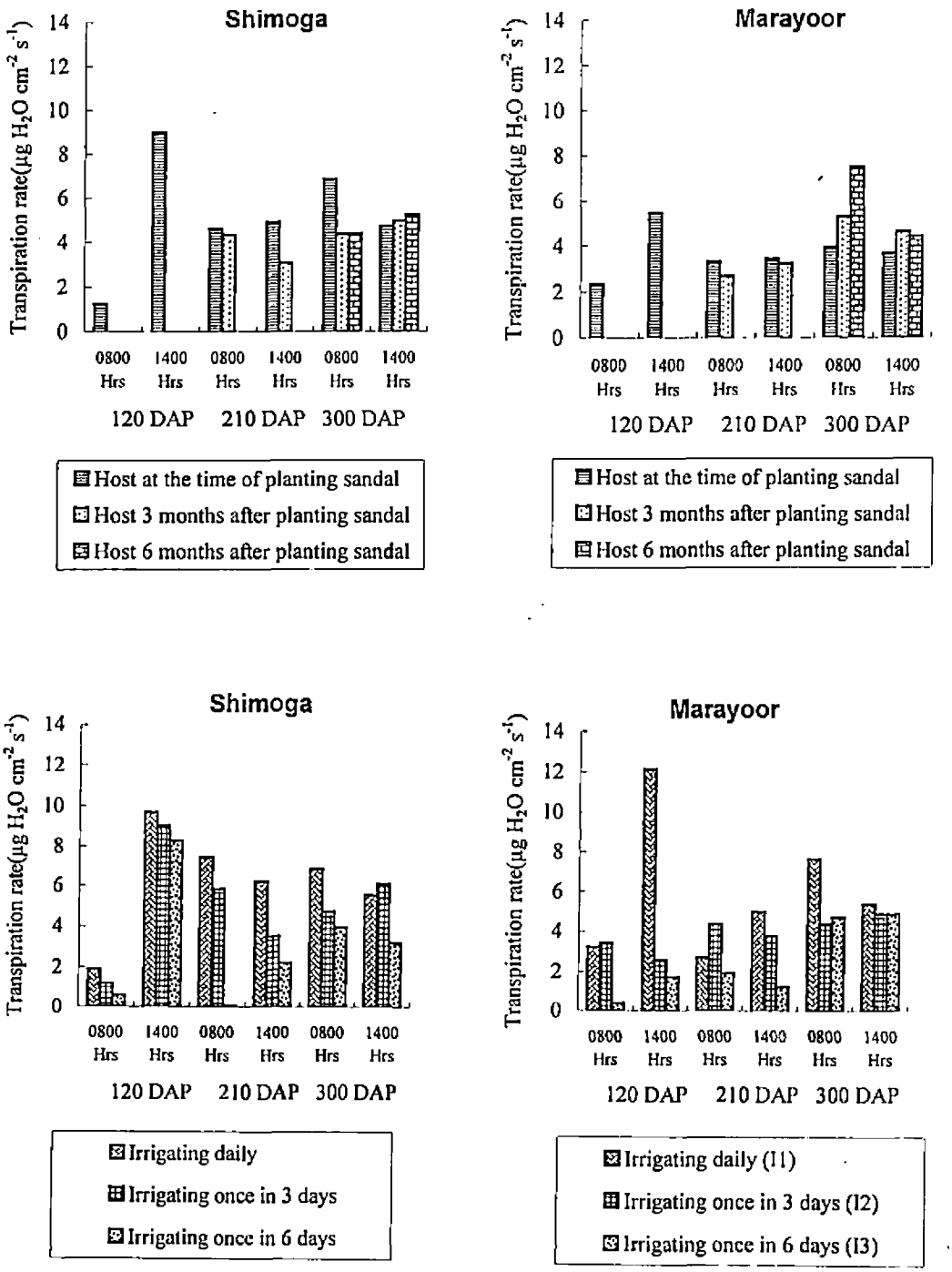


Fig. 22. Transpiration rate of host seedlings as affected by stage of its introduction with sandal in Shimoga and Marayoor provenance and at various levels of water stress

Table 64. Leaf temperature (°C) in *C. cajan* seedlings as affected by introducing with *S. album* at various stages and in different levels of water stress

Provenances	Days after planting											
	120 DAP				210 DAP				300 DAP			
	Shimoga 0800 Hrs	Marayoor 0800 Hrs	Shimoga 1400 Hrs	Marayoor 1400 Hrs	Shimoga 0800 Hrs	Marayoor 0800 Hrs	Shimoga 1400 Hrs	Marayoor 1400 Hrs	Shimoga 0800 Hrs	Marayoor 0800 Hrs	Shimoga 1400 Hrs	Marayoor 1400 Hrs
Time of host introduction												
At the time of planting sandal	25.47^{b}	26.07^{a}	36.67^{a}	36.17^{b}	31.24^{c}	32.92^{a}	32.90	32.41	27.33	28.07	31.83	31.57
3 months after planting sandal	HNI	HNI	HNI	HNI	30.93^{c}	32.39^{b}	32.98	32.56	27.41	27.90	31.67	31.66
6 months after planting sandal	HNI	HNI	HNI	HNI	HNI	HNI	HNI	HNI	27.50	27.80	32.07	31.19
P	-----				0.025		NS		NS		NS	
Irrigation												
Daily	25.47	26.27	36.73	36.23	31.28	32.63	32.83^{b}	32.45^{c}	27.34	28.17	31.91	31.29
Once in three days	25.57	25.80	36.50	36.07	31.07	32.78	32.82^{b}	32.45^{c}	27.32	27.92	31.96	31.36
Once in six days	25.37	26.13	36.77	36.20	30.92	32.55	33.17^{a}	32.55^{c}	27.58	27.68	31.64	31.77
P	NS		NS		NS		0.004		NS		NS	
Provenance Mean	25.47	26.06	36.66	36.16	31.08	32.65	32.94	32.48	27.41	27.92	31.84	31.47
P	NS		NS		NS		0.031		NS		NS	
SEm ±	0.231		0.130		0.305		0.096		0.164		0.107	

HNI – Host was not introduced at this stage

At almost all the stages, the increase in the water stress increased the leaf temperature of the red gram seedlings irrespective of the sandal provenance. However it was significant only at 210 DAP at 1400 H where seedlings introduced in Shimoga provenance showed a higher leaf temperature as compared to seedlings in Marayoor provenance.

4.6 CO-RELATION OF WATER POTENTIAL WITH NUTRIENT CONTENT

The co-relation of water potential and nutrient content is shown in Table 65. The water potential at 120 DAP is co-related to P content of the seedlings at 5 per cent level in Shimoga provenance whereas K is negatively co-related to water potential in Marayoor provenance. At 210 DAP N is negatively co-related to water potential in Shimoga provenance whereas Ca is highly co-related to water potential in Marayoor provenance. Finally, Na in seedlings of Shimoga provenance is co-related to water potential at 300 DAP whereas both N and P is correlated to water potential at 300 DAP in Marayoor provenance.

Table 65. Co-relation between water potential and nutrient content of *Santalum album* seedlings.

Provenances	Shimoga			Marayoor		
	Water potential 120 DAP	Water potential 210 DAP	Water potential 300 DAP	Water potential 120 DAP	Water potential 120 DAP	Water potential 120 DAP
Nitrogen	0.046	-0.438*	0.176	0.147	0.201	-0.582**
Phosphorus	0.455*	-0.177	-0.148	-0.127	-0.043	0.386*
Potassium	0.151	-0.210	0.141	-0.457*	-0.018	0.165
Sodium	0.238	-0.040	0.436*	-0.135	-0.036	0.034
Calcium	-0.177	0.208	-0.223	0.024	0.508**	0.154

* significant at 5% level
** significant at 1% level

DISCUSSION

5. DISCUSSION

Sandal-host interactions are so complex that the role of host plants in sandal growth are not clearly understood. The question whether sandal needs a host from the very beginning of the seedling growth or only during the later stages is one aspect addressed under this project. The complementary influence of host plants on sandal nutrition are dealt with in great detail in most of the earlier studies (Iyengar, 1965; Ananthapadmanabha *et al.*, 1984; Rangaswamy *et al.*, 1986). However, the results are not convincing to conclude about the nutrients derived from the host. The role of the host plants on internal water balance of sandal was not investigated much. When there is water stress, whether the host will compete or complement the water requirement of sandal is another aspect addressed here. The difference in response of two provenances, one from Kerala (Marayoor) and another from Karnataka (Shimoga) to soil moisture stress and the host relationships are also discussed in the light of the results obtained.

5.1 GROWTH PARAMETERS OF SANDAL

Considerable variations were observed in growth characters like height, collar diameter, leaf area and root growth of sandal due to the difference in provenance, the presence of host and water stress. However, all the responses observed could not be attributed to the sandal-host parasitic relationships. As the haustorial connections between sandal and host were observed only at 300 DAP, the variations obtained in sandal growth due to the presence of host, until 300 DAP could not be attributed to the host-parasite relationships. The introduction of host at the time of planting and three months after planting sandal reduced the collar diameter of the seedlings in both the provenances.

In general, a decrease in the growth parameters like height, girth, number of leaves and leaf area observed due to the presence of host during the early seedling phase of sandal may be due to competition from the host plants. The competition may be for nutrients, water and/or solar radiations. As the nutrient content and the plant water potentials were not consistently influenced by the host plants, the early decrease in

growth parameters observed may be due to the shade cast by the host seedlings on the sandal.

Kamalolbhavan (2002) observed that the number of leaves were least for sandal seedlings grown under 75 per cent shade. The reduction in number of leaves in response to water stress was observed in *Eucalyptus maculata* and *E. brockwayii* (Myers and Landsberg, 1989) and *Fagus sylvatica* (Cermack *et al.*, 1993). Also, the number of leaves and leaf area showed a decreasing trend with increasing water stress levels in *Ailanthus triphysa, Acacia mangium, Swietenia macrophylla, Pterocarpus marsupium* and *Tectona grandis* (Rajesh, 1996). Where more than one plant is grown close together the chance of interactions, both intra and inter species are possible and may result in complementary and competitive responses (Wiley, 1982). More over, even though sandal may form haustorial connections with the roots of host and extract the mineral nutrients and water for its growth, the above ground competition for light and space from host plants cannot be ruled out. The reduction in the leaf area observed during the later phase of sandal seedlings may be due to the prevailing dry weather (Appendix I), which increased the leaf abscission (Plate 6). Ludlow and Muchow (1990) attributed the reduction in leaf area to increased abscission.

As the levels of water stress increased, the plant height showed a decrease in Shimoga provenance whereas in Marayoor provenance, there was no significant difference observed in height due to water stress. Probably Marayoor provenance is having inherent ability to tolerate water stress as compared to Shimoga provenance. The primary effect of water stress is the reduction in turgor, which retards the cell elongation, and this in turn affects the internodal elongation of plants. Reduction in stem elongation due to water stress was also observed in loblolly pine (Cannel *et al.*, 1978), *Picea rubens* (Robert and Cannon, 1992) seedlings. Rajesh (1996) reported a reduction in shoot elongation rate in *Ailanthus triphysa, Acacia mangium, Swietenia macrophylla, Pterocarpus marsupium* and *Tectona grandis* due to water stress.

As the level of water stress increased, there was a decrease in the collar diameter of the seedlings in both the provenances. The decreases were more prominent

Plate 6. Abscission of leaves in sandal seedlings.

in seedlings watered once in six days as compared to seedlings watered daily and once in three days. Up to 90 per cent of the annual variation in the xylem increment of the forest trees has been attributed to the water deficits in the arid region and up to 80 per cent in the humid regions (Zahner, 1968). Several aspects of cambial activity, including division of fusiform cambial cells and xylem mother cells as well as enlargement and differentiation of cambial derivatives, are very sensitive to changes in water balance. The adverse interference on cambial growth of *Acacia auriculiformis* due to water stress was observed by Kallarackal and Somen (1992).

Sandal seedlings with host plant at the time of planting sandal resulted in lower root length in both the provenances (120 DAP) as compared to introduction of host at three or six months after planting sandal. Observations on root length made at 210 DAP showed no significant difference due to the difference in date of host introduction. The decrease in the root length observed in both the provenances at 120 DAP and in Shimoga provenance at 300 DAP may be due to the competition from host plant. Decrease in root length due to the competition from the component plants are reported in multi cropping systems involving Grivellia and Maize (Lott *et al.*, 2000); Bamboo, Vateria and Teak (Divakara *et al.*, 2001) and ginger and *Ailanthus triphysa* (Thomas *et al.*, 1998). Competition from adjoining roots for resources can result if either roots of the plants deplete the soil resources more quickly than roots of another, or roots of the more successful competitor deplete resources to levels below which other plant roots can extract sufficient quantities for growth and survival (Tilman, 1982).

Water stress increased length of roots irrespective of stage of host introduction. The lower water content in the soil might have induced the root to grow more in search of water. Similar responses were observed in *Acacia mangium* (Awang and DeChavez, 1993); the water stress increased the root growth capacity.

In both the provenances, there was no difference in shoot dry weight because of the presence of host up to six months of planting sandal. This view was also corroborated by the data on haustorial connections (Table. 21). The haustorial connections were established 300 days after planting sandal. The data at 300 DAP

showed no significant differences due to the introduction of host in the early phase of sandal seedlings. This is true with respect to dry root weight and total dry matter production also.

At this stage, the total dry matter produced was not significantly influenced by the date of host introduction. So, it is obvious that the introduction of host during the first six months is not having significant influence on the total dry matter production of sandal.

Water stress resulted in considerable decrease in the dry weight of shoot and root, and ultimately total dry matter production. This was consistently evident from the observations made at 210 and 300 DAP. Total dry matter production was minimum when the plants were water stressed for six days and maximum dry matter production was in plants which were irrigated daily. Marayoor provenance produced more dry matter than Shimoga at all the water stress levels, indicating the relative tolerance of Marayoor provenance to water stress, as compared to the Shimoga provenance this was also evident from the height of the sandal seedlings under moisture stress.

The host plants did not improve the water status of sandal under stress. Considering the results of the present experiment, the present recommendations of the requirement of a pot host for sandal right from the seedling stage needs further evaluation. Radomiljac (1998) observed that the growth and dry matter production of sandal is improved due to the presence of a pot host. In Sri Lanka pot hosts of *Phaseolus mungo* and *Cosmos sulphurous* resulted in marked improvement in height, collar diameter and dry weight of one year old sandal seedlings (Tennakoon *et al.*, 2000). Red gram, the pot host suggested in India is fast growing, tall and over grow sandal and suppresses sandal growth. As haustorial connections are formed only at 300 DAP, the need for pot host is doubtful. It is also necessary to look for slow growing, spreading type of pot hosts, which may not compete with sandal.

5.2 PHYSIOLOGICAL PARAMETERS OF SANDAL

Significant variations in pre-dawn water potential were observed between provenances and due to the difference in date of introduction of host. During all the

stages of observation (120, 210 and 300 DAP) the seedlings of Marayoor provenance recorded lower pre-dawn water potential as compared to Shimoga provenance. Lower water potential may enhance the efficiency of the plant in extracting soil moisture during drought. The water stress tolerance showed by Marayoor provenance may be because of this reason. The growth pattern of Marayoor provenance under water stress corroborates this viewpoint.

The results also indicate that host plants may be helping the sandal plants to maintain higher water potential, as the water potential of sandal was higher in the presence of host. The probability of host plants contributing to maintain the internal water balance of sandal cannot be ruled out as the haustorial connections between sandal and host were reported to reach up to the xylem of the host plant (Taide, 1992). Tennakoon *et al.* (2000) from Sri Lanka observed that the sandal seedlings always showed more negative water potential than the associated host plants thus maintaining a water potential gradient favourable to sandal seedlings to derive water and nutrients from the host.

Water stress decreased the water potential of both sandal and host. So the host plants may not be in a situation to contribute to the internal water balance of sandal. When the soil moisture stress is considerable, sandal as well behaved just like any other plant exposed to water stress. Rajesh (1996) observed a lower water potential in water stressed *Pterocarpus marsupium* and *Acacia mangium*.

There was no significant difference in leaf diffusive resistance in both the provenances due to the introduction of host plants. The leaf diffusive resistance was high in both the provenances at 0800 hrs as compared to the observations made at 1400 hrs. The stomata in sandal may be more open during afternoon hours. Stomatal opening and closing in plants are influenced among other things, by solar radiation temperature and humidity (Kozlowski *et al.*, 1991). The stomata in sandal may be slow to respond to sunlight and solar radiation at 0800 hrs, was low to induce stomatal opening. The resistance was relatively higher when the host was introduced at the time of planting sandal in Marayoor provenance. The host plants growing with sandal had a significant

influence on the stomatal resistance of the seedlings probably because of the shade and the microclimate influences. Partial closure of stomata in water deficit situation has been reported in many tree species (Kozlowski, 1982). Water stress influenced the leaf diffusive resistance during 120 and 210 DAP especially at 1400 hrs. It is only logical that the water stress responses are more evident during the afternoon. Also, it has been reported that water stress becomes a factor for stomatal closure when the water potential falls quite low (Landsberg and Jarvis, 1976).

At 300 DAP the seedlings of Shimoga provenance where the host was introduced six months after planting sandal and watered daily showed highest leaf temperature whereas seedlings of Marayoor provenance, which were watered once in three days and host introduced six months after planting sandal recorded the lowest leaf temperature. Plants after intercepting light more than saturation point for photosynthesis, will automatically increase the leaf temperature. To dissipate this heat, plants may transpire more (Landsberg, 1986) which may lower the leaf temperature. As the levels of water stress increase, the stomata of the sandal leaves may be closed, which results in the reduction of transpiration and increase in leaf temperature.

The chlorophyll 'a' and 'b' and total chlorophyll content were higher in seedlings where the host was introduced at the time of planting sandal in both the provenances as compared to seedlings where the host was introduced three and six months after planting sandal. The higher chlorophyll content observed may be due to the alleviation of solar radiation by the host plants resulting in less photo destruction of chlorophyll in sandal. Higher light intensities are reported to destroy chlorophyll (Alberte *et al.*, 1977). As the level of water stress increased, there was a decrease in the chlorophyll 'a' content of the seedlings. In both the provenances, the increase in water stress and the introduction of host at later stages decreased the total chlorophyll and this response was more prominent in Shimoga provenance. Tennakoon *et al.* (2000) observed an increase in chlorophyll content and carbon fixation rates where sandal seedlings were planted with a pot host.

5.3 NUTRIENT CONTENT OF SANDAL

Though the influence of host plants on N, P, K, Na and Ca content of sandal seedlings showed significant variations, a consistent pattern was not observed.

Iyengar (1965) reported that the dependence of sandal on the host is mainly for N and P, where as it can directly absorb Ca and K. Then Rangaswamy *et al.* (1986) suggested that sandalwood depend on its host for P, K and that in the absence of a host plant, it is incapable of growing normally.

The correlation between the plant nutrient content and the water potential also did not reveal any definite trend (Table 42). The water potential at 120 DAP is correlated to P content of the seedlings in Shimoga provenance whereas K is negatively correlated to water potential in Marayoor provenance. At 210 DAP, N is negatively correlated to water potential in Shimoga provenance whereas Ca is highly correlated to water potential in Marayoor provenance. Sodium in seedlings of Shimoga provenance is correlated to water potential at 300 DAP whereas both N and P is correlated to water potential at 300 DAP in Marayoor provenance. So the role of any of these nutrients in osmotic adjustment and regulating plant water potential could not be confirmed.

5.4 CORRELATION BETWEEN GROWTH OF HOST AND SANDAL

Except in Shimoga provenance at 300 DAP, the shoot height of both the provenances were negatively correlated with the height of the host plant indicating the competitive relation between the host and sandal at the early growth stages. It is evident that there was no haustorial connections between sandal and red gram seedlings up to 300 DAP (Table 21). So, it is obvious that the height of both red gram seedlings and sandal seedlings were not affected by host parasite relations, and on the other hand, may be competiting each other for the soil moisture and nutrients.

The root length of sandal and red gram seedlings were also negatively correlated in both the provenances. As the haustorial connections were already formed by 300 DAP, the growth of the roots of sandal and host may be hindering each other and hence were negatively correlated.

host. So, the necessity of a pot host is questionable. The only advantage is that if a pot host is introduced, it may form haustorial connections by the time it is transplanted in the main field. It may also be desirable to select a pot host plant that may not over grow sandal, especially during early phase, as no benefits are derived from the host during the early phase of sandal growth.

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The levels of water stress affected the water potential of the red gram seedlings at all the stages. As the levels of water stress increased, there was a decrease in the water potential of the red gram seedlings and was more pronounced in the seedlings introduced in Marayoor provenance. It may be recalled that the Marayoor provenance had lower pre-dawn plant water potential as compared to Shimoga. This low plant water potential enables the seedlings of Marayoor provenance to extract soil moisture more efficiently as compared to the host red gram, which obviously is more resistant to water stress. The water potential of the host (red gram) and sandal except in Shimoga provenances at 120 DAP, were positively correlated, in both the provenances. This indicates that when there is no water stress both sandal and red gram are having a complementary effect on maintaining the plant water potential.

The overall results points to the negative influence of host plants on growth parameters of sandal during early phase of sandal growth. These observations are corroborated by the physiological and morphological responses observed. As the haustorial connections are formed only at 300 DAP, evolutionarily the species may be autotrophic during the early phase. Haustorial development may take about ten months. So, host-parasite relation in sandal after this stage is more important and needs a detail study. Fast growing pot host during the early phase of sandal growth may suppress its growth by competition. Irrespective of the stage of host introduction, the number of haustoria formed was same in sandal. The number of haustoria formed by sandal did not vary when the host was introduced at the time of planting sandal, three months after planting sandal or six months after planting sandal. In all these situations, haustoria were observed only ten months after planting sandal (300 days after planting sandal). So it is not the length of association between sandal and the host that govern the haustoria formation, it may be a physiological stage in sandal. A minimum physiological growth of the seedlings is required before the haustoria differentiates. It is reported that the sandal roots form haustoria with soil particles or other inert material which the root come into contact (Ananthapadmanabha *et al.*, 1984). In our study also it was observed that sandal haustoria are formed to the sides of poly bags in which they were grown.

From these results, it is deduced that the host need to be planted only six to ten months after planting sandal. This will avoid the early competition between sandal and

host. So, the necessity of a pot host is questionable. The only advantage is that if a pot host is introduced, it may form haustorial connections by the time it is transplanted in the main field. It may also be desirable to select a pot host plant that may not over grow sandal, especially during early phase, as no benefits are derived from the host during the early phase of sandal growth.

SUMMARY & CONCLUSIONS

6. SUMMARY AND CONCLUSIONS

Experiments were conducted at College of Forestry, Kerala Agricultural University, Vellanikkara during 2002-2003 to study the influence of stage of host introduction and soil moisture stress on seedling provenances of sandal (*Santalum album* Linn.). The salient features of the study are summarized below:

1. The seedlings of Marayoor provenance were taller and having a higher collar diameter as compared to seedlings of Shimoga provenance and the stage of host introduction did not have any positive effect on the growth of the sandal seedlings. During the early phase host decreased the sandal growth.

2. Water stress showed a deteriorating effect on parameters like seedling height, collar diameter, number of leaves, leaf area, dry matter and chlorophyll content.

3. The root length was more in seedlings of Shimoga provenance and there was an increase in the root length when both sandal and host seedlings were introduced at the same time, in both the provenances.

4. Introduction of host during the first six months is not having significant influence on the total dry matter production of sandal.

5. The haustorial connections were found only at 300 days after planting sandal and host.

6. The seedlings of Marayoor provenance recorded lower pre-dawn water potential as compared to Shimoga provenance. Introducing host at the time of planting and three months after planting sandal in Marayoor provenance resulted in higher water potential.

7. The leaf diffusive resistance was relatively higher when the host was introduced at the time of planting sandal in Marayoor provenance and the stomatal resistance was high in stressed plants.

8. The seedlings of Shimoga provenance recorded a lower leaf temperature as compared to seedlings of Marayoor provenance irrespective of stage of host introduction.

9. The seedlings where the host was introduced at the time of planting sandal had comparatively higher total chlorophyll in both the provenances as compared to seedlings where the host was introduced three and six months after planting sandal.

10. Highest N content was observed in Marayoor provenance when the host was introduced at the time of planting sandal.

11. In both the provenances, P content was significantly higher when the host was introduced at the time of planting sandal.

12. When the hosts were introduced six months after planting sandal, K content showed an increasing trend with the increase in the levels of water stress.

13. The seedlings of Marayoor provenance where the hosts were introduced at the time of planting sandal had higher Ca content.

CONCLUSIONS

The seedlings of Marayoor provenance performed better as compared to seedlings of Shimoga provenances with respect to most of the parameters. As the haustorial connections were found only at 300 days after planting sandal, the necessity of host during early phase needs review. However, a conclusion cannot be arrived at without follow up studies on the performance of these plants in the field. It can be concluded that the host need to be planted only six to nine months after planting sandal. This will avoid the early competition between sandal and host. Fast growing pot host during the early phase of its growth may suppress sandal by competition. Field evaluation of sandal as a component crop in the homesteads/agro forestry systems and its effects need to be taken up with appropriate management inputs for increasing the production of sandal.

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Chapter 4. ANOVA

pp. 41-49

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* Originals not seen.

APPENDICES

APPENDIX - I

Weather parameters during the study period (October 2002 to August 2003)

	Temperature (^{0}C)		RH (%)			Rainfall(mm)	
Year	Maximum	Minimum	Morning	Evening	Mean RH	Rainfall	Rainy days
Oct '02	30.8	23.2	92	74	83	387.7	19
Nov '02	31.8	23.4	82	60	71	22.1	3
Dec '02	32.3	22.1	72	45	45	0	0
Jan '03	33.2	22.9	66	34	50	0	0
Feb '03	34.7	23.6	83	43	63	162.1	5
Mar '03	34.6	24.1	86	47	67	94.8	4
Apr '03	34.6	25	86	58	72	23.8	3
May '03	34	25	88	56	72	40.3	3
Jun '03	30.9	23.8	91	68	80	570.6	19
Jul '03	29.5	22.2	93	74	84	492.6	22
Aug '03	30	23.4	93	73	83	490.1	19

INFLUENCES OF SOIL MOISTURE REGIMES AND STAGE OF HOST INTRODUCTION ON SEEDLING GROWTH OF SANDAL PROVENANCES

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ABSTRACT OF THE THESIS

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ABSTRACT

The influence of soil moisture regimes and stage of host introduction on seedling growth of sandal provenances was investigated in a pot culture experiment at the College of Forestry, Kerala Agricultural University, Vellanikkara. Two provenances in the South India, Shimoga (Karnataka) and Marayoor (Kerala) were selected for this study.

The results showed that the seedlings of Marayoor provenance were taller and having a higher collar diameter as compared to seedlings of Shimoga provenances. The stage of introduction of host did not have any effect on the growth of sandal seedlings. The seedlings where the host was introduced at the time of planting sandal had comparatively higher total chlorophyll in both the provenances as compared to seedlings where the host was introduced three and six months after planting sandal. Highest Nitrogen and Calcium content was observed in Marayoor provenance when the host was introduced at the time of planting sandal, whereas the P content was higher in both the provenances where the host was introduced at the time of planting sandal.

The parameters like seedling height, collar diameter, number of leaves, leaf area, dry matter and chlorophyll content decreased due to water stress.

The haustorial connections were found only at 300 days after planting sandal. The seedlings of Marayoor provenance recorded lower pre-dawn water potential as compared to seedlings of Shimoga provenance. Introducing host at the time of planting sandal or three months after planting sandal, in Marayoor provenance resulted in higher plant water potential. The leaf diffusive resistance was relatively high in Marayoor provenance when the host was introduced at the time of planting sandal. The leaf diffusive resistance was high in water stressed plants.

As the haustorial connections were found only at 300 days after planting sandal, it can be concluded that the host need to be planted only six to nine months after planting sandal. This will avoid the early competition between sandal and host. Fast growing pot host during the early phase of its growth may suppress sandal by competition.