INFLUENCE OF HOST PLANT ON THE PHYSIOLOGICAL ATTRIBUTES OF FIELD-GROWN SANDAL TREE (*SANTALUM ALBUM*)

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ROCHA D, ASHOKAN PK, SANTHOSHKUMAR AV, ANOOP EV & SURESHKUMAR P. 2014. Influence of host plant on the physiological attributes of field-grown sandal tree (*Santalum album*). This paper examines the influence of host plant, *Casuarina equisetifolia,* on carbon assimilation, water and nutrient absorption in a 6-year-old field-grown sandal tree. Sandal trees growing with host showed carbon assimilation rate of 17.66 µmol cm^{-2} s^{-1} whereas sandal trees growing without host plant showed only 15.13 µmol cm^{-2} s^{-1}. Sandal tree growing with host plant also showed higher pre-dawn plant water potential (-0.85 MPa) than sandal tree without host plant (-1.27 MPa). Leaf nutrient contents were higher in sandal tree with host plant (N = 2.65%, K = 0.24%, P = 2.31%) compared with sandal tree without host plant (N = 2.48%, P = 0.16%, K = 1.68%). The host plant supplemented N, P and K requirement of sandal trees through haustorial connections. The most outstanding influence of the host plant was in increasing the K status of sandal tree. Sandal tree depended on host plant mainly for maintaining plant water level and reducing water stress and the K status of the leaf played significant role in this. Host plant was not only essential for initial establishment of sandal tree but was also required in the main field.

Keywords: *Casuarina,* carbon assimilation, haustoria, leaf water potential

INTRODUCTION

Santalum album (East Indian sandal wood or sandal tree) is a small evergreen hemi-parasitic tree renowned for its fragrant heartwood and is synonymous with ancient Indian culture and heritage (Srinivasan et al. 1992). *Santalum album* is indigenous to India and its distribution is limited to an area of about 9600 km^2, mostly in the deciduous forests of Deccan region of Peninsular India (Gairola et al. 2008). The south Indian states of Karnataka and Tamil Nadu together account for more than 90% of the natural population of *S. album* in India (Dutt & Verma 2005). Sandal tree forests in Kerala are mainly located on the drier parts of eastern side of the Western Ghats in the Anjanad valley of Marayoor range in Munnar Forest Division (Hiremath 2004). On a limited scale, sandal trees are also found in Ariankavu range of Thenmalai Forest Division. Isolated patches of sandal tree are also found in Walayar, Wadakancherry and Plamaram (Palghat district) forest areas. Sandal tree is also observed as a component of the homestead especially in northern Kerala (Kumar et al. 1994).

The production of sandal tree in India dropped from 4000 Mg heartwood per year in the 1950s to a mere 500 Mg in 2007 despite global annual demands of 5000 to 6000 Mg for its wood and 100 to 120 Mg for its oil (Gairola et al. 2008). The depletion of sandal tree forest is attributed to factors such as spike disease, recurrent annual fires (Rai 1990), invasive weeds including *Lantana camara* and spread of monoculture plantations of *Eucalyptus* (Basappanavar 1977), illicit felling and smuggling (Rao et al. 1999). Illicit felling and smuggling are very rampant and are the major problems in the sandal tree-growing states.

High economic value of sandal wood provides sufficient incentives to farmers for growing this tree on a commercial scale. However, the area under sandal tree is decreasing fast because of pilferage and difficulty in field establishment of sandal tree in new areas. The gap between demand and supply is so wide that the prices of sandal wood and oil are currently extremely high. The current price for sandal wood is Rs6,000,000 per tonne (~USD125,000) and the price of sandal oil is Rs135,000 (~USD2200) per kg

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(Ananthapadmanabha et al. 1984). Considering the high demand and diminishing supply of sandal tree, there is great potential for raising it, not only in forest lands but also in private lands such as home gardens and other agroforestry systems.

Regeneration and establishment of sandal tree have been problematic because of poor understanding of host–parasite relationships (Surendran et al. 1998). Three stages of parasitism have been identified for the successful establishment of *S. album* plantations (Ehrhart & Fox 1995). These are (1) in pot hosts (initial or primary)—the primary host is planted into a container having *S. album* seedling during nursery propagation, (2) intermediate hosts (bridging nursery and field) and (3) long-term (secondary) hosts. Studies have shown that host plants influence mineral nutrient and water uptake by sandal tree seedlings (Varghese 1997, Hiremath 2004). Although there is unanimity in accepting the hemi-parasitic nature of sandal tree, there is no consensus on the mineral elements and/or carbon assimilates that are extracted by sandal tree from host plants in field-grown conditions. Most of the studies on sandal tree–host interactions were done during the seedling stage. The physiological interactions of field-grown sandal trees with host plants are not known. Considering these factor, field experiments were carried out to understand the influence of *Casuarina* (host plant) on carbon assimilation, plant water potential and nutrient status of sandal tree grown in the field.

MATERIALS AND METHODS

Investigations were carried out in a 6-year-old sandal tree plot maintained at the College of Forestry, Kerala Agricultural University, Vellanikkara, Thrissur district, Kerala in 2009–2011. The study location lies between 10° 32' N and 76° 16' E and experiences warm humid climate with mean annual rainfall of 2669 mm, most of which is received during the south-west monsoon (June till August). Mean maximum temperature ranges from 28.9 °C (July) to 36.2 °C (March) and mean minimum temperature ranges from 22 °C (January) to 24.6 °C (May). Soil of the experimental site is of lateritic origin. To understand the influence of the host plant (*Casuarina*) on carbon assimilation, water and nutrient status in sandal tree grown in field, the experiment was conducted in 6-year-old sandal trees with three treatments, namely, H_0 = sandal tree without host (i.e. selected sandal plants where the host plant *Casuarina* died naturally within 2 years after establishment of sandal tree in the field), H_1 = sandal tree with host, H_2 = sandal tree with host and the host plant was felled at 6-year stage of growth. Single plant experimental plot with spacing of 2 m × 2 m was used. The study was conducted in a randomised block design with three treatments mentioned above and 10 replications.

Carbon assimilation rate (photosynthesis) of sandal tree growing with and without host plant in different seasons and water potential of sandal tree before and after 30 days of removal of host plant were monitored. The carbon assimilation rate was measured using a portable photosynthesis system and plant water potential was estimated using a pressure bomb type plant water status console. Fresh leaves of sandal trees were analysed for nutrient contents. Leaves were collected at random from different areas of the canopy, kept in paper bags and oven dried at 60 ± 5 °C until constant weight was achieved. The dried samples were ground, mixed and analysed for nitrogen (N), phosphorus (P), potassium (K), iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn). Nitrogen was determined using Micro-Kjeldahl method. Phosphorus was determined using Vanado-molybdo-phosphoric yellow colour method in HNO_3 (Koening & Johnson 1942). An aliquot of the diacid digest of the leaf samples was used for estimating K content in a digital flame photometer. An aliquot of the diacid digest of leaf samples was also used for the estimation of micronutrients, namely, Fe, Cu, Zn and Mn in an atomic absorption spectrometer.

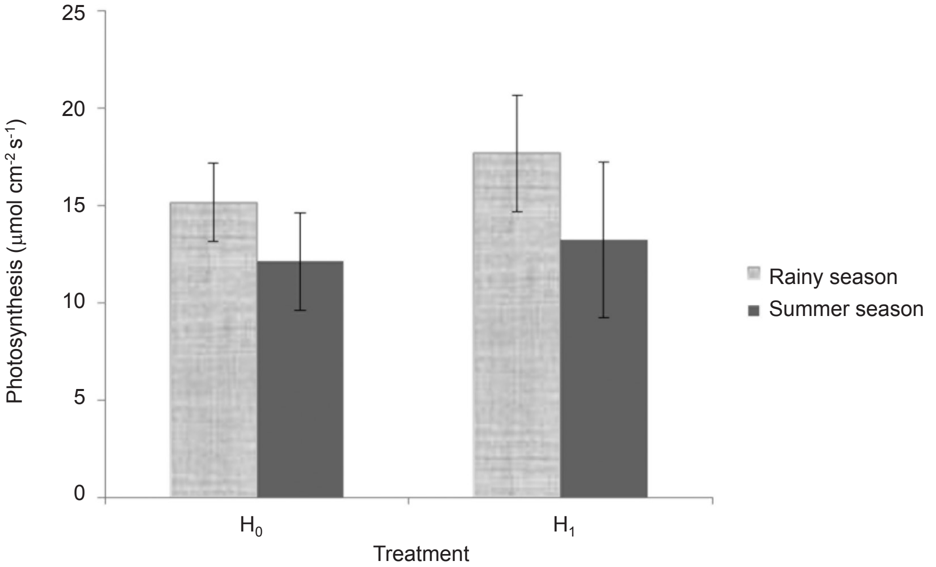
Two sandal trees, one with and the other without host, were excavated to investigate the haustorial association. Soil of one quarter of the area, 1-m radius and 30-cm depth, around the sandal tree was carefully removed by loosening the soil with water spray and a fork. The number of functional and non-functional haustoria on primary, secondary and tertiary roots of host was recorded.

RESULTS AND DISCUSSION

Sandal trees grown with host plant showed significantly higher ($p < 0.05$) rate of carbon assimilation (Figure 1). The increased rate of carbon assimilation observed in sandal tree with host plant is an indication that in the long run, host plants may help sandal tree grow faster and accumulate more biomass and heartwood.

Sandal tree growing with host showed significantly higher ($p < 0.05$) plant water potential. It have been reported that seedlings of sandal growing with host plants have better plant water status, indicating that the host plant is supporting the sandal tree to absorb more water from the soil (Varghese 1997, Hiremath 2004, Dhaniklal 2006, Ashokan & Krishnambika 2007).

Plant water potential of sandal tree before the removal of host plant is shown in Figure 2a. Significant differences ($p < 0.05$) were observed between treatments of sandal tree growing with and without host plants. The sandal tree growing without host plant showed lower plant water potential compared with sandal tree growing with host removed after 6 years. Plant water potential of sandal tree after removal of host plant is shown in Figure 2b. Sandal tree with host showed significant reduction in water potential after the removal of host plant.



H_0 = Sandal tree without host
H_1 = Sandal tree + *Casuarina*—throughout the experiment

Figure 1 Effect of host *Casuarina* on photosynthesis of sandal tree in different seasons

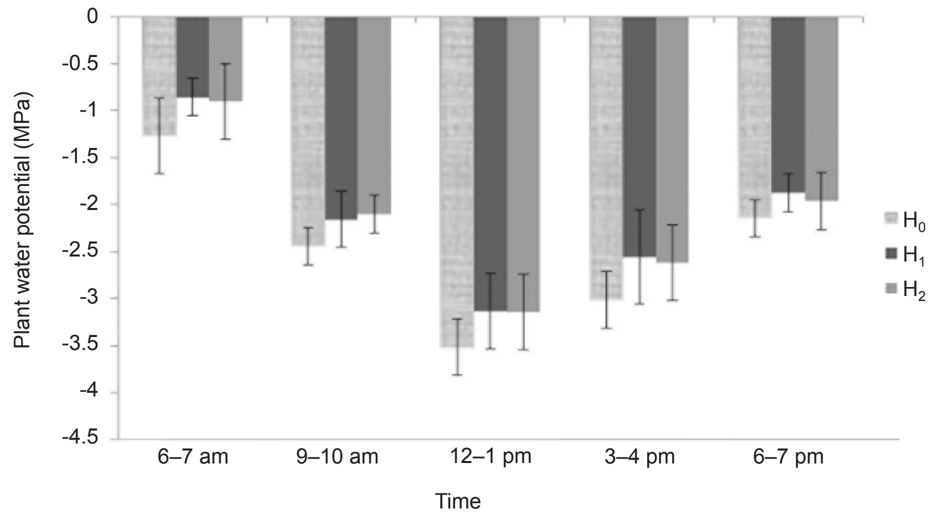


Figure 2 (a) Effect of host *Casuarina* on plant water potential of sandal tree before removal of host; H_0 = sandal tree without host, H_1 = sandal tree + *Casuarina*—throughout the experiment, H_2 = sandal tree + *Casuarina*—host removed after 6 years

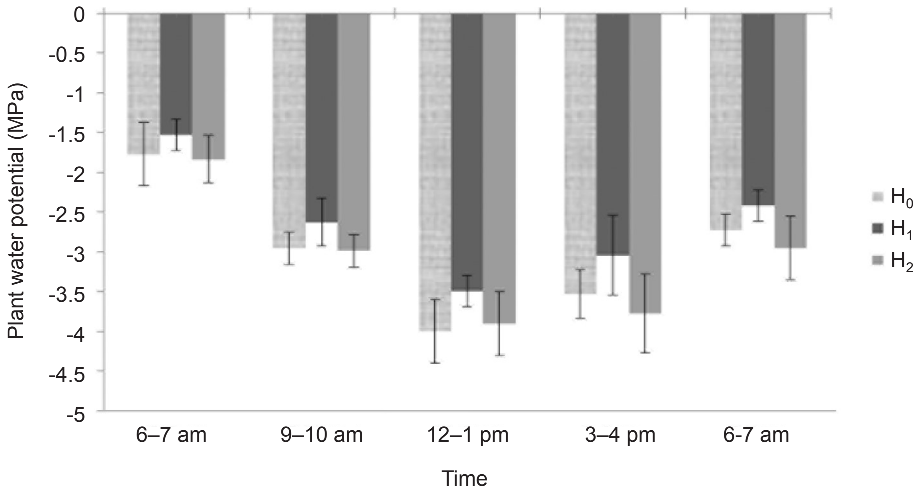


Figure 2(b) Effect of host *Casuarina* on plant water potential of sandal tree, 30 days after removal of host; H_0 = sandal tree without host, H_1 = sandal tree + *Casuarina*—throughout the experiment, H_2 = sandal tree + *Casuarina*—host removed after 6 years

The reduction in water potential of sandal tree after removal of host was also corroborated by the observation of wilting and leaf shedding of the sandal tree (Figure 3). Obviously, the host plant was supporting the sandal tree to maintain better plant water status. In the absence of the host plant, the sandal tree may be stressed for water, which may in turn affect the growth of sandal tree and its productivity.

Interactions of sandal tree and host plant for the uptake and translocation of various mineral nutrients were reported by different authors (Ananthapadmanabha et al. 1984, Rangaswamy et al. 1986, Brand 2002). However, their reports showed wide variations and no conclusions on the requirement of host plant for absorption of mineral nutrient. The current study revealed that there was no considerable variation in the micronutrient content of sandal tree in the presence or absence of host plant. However, significant variations ($p < 0.05$) were observed in the macronutrient content of sandal tree growing with host plant. Sandal tree grown with host plant showed higher contents of N, P and K in their leaves (Table 1). Subsequent reduction in the leaf-nutrient status of sandal tree after removal of host plant also supported the conclusion that a higher nutrient status was maintained in sandal tree with the support of host plant. Potassium content of sandal tree leaves decreased from 2.53 to 1.50% on removal of the host plant (Figure4). The role of K in regulating water in plants is well established; its role in osmotic regulations and stomatal movements is well researched (De Costa & Liyanage 1997). The removal of host plant also decreased water potential of sandal tree, indicating the dependence of sandal tree on the host plant for maintaining water potential and the probable role of internal K balance in maintaining water potential.

Figure 3 Wilting and leaf shedding of sandal tree after removal of host plant

Root excavation of sandal tree with and without host plant was conducted to investigate the haustorial associations. The parasitic nature of sandal tree by the formation of haustoria in different host species have been reported by various researchers (Rao 1911, Venkatarao 1938, Srimathi & Sreenivasaya 1962, Iyengar 1965). However, most parasitic and physiological

Table 1 Effect of the host plant on the leaf nutrient content of sandal tree

	N	P	K	Fe	Zn	Mn	Cu
	Percentage			mg kg^{-1}			
Sandal tree (H_0)	2.54 b	0.15 b	1.78 b	436 a	21.31 a	495 a	20.29 a
Sandal tree + *Casuarina* (H_1)	2.63 a	0.25 a	2.49 a	445 a	20.48 a	502 a	21.47 a
Sandal tree + *Casuarina* (H_2)	2.73 a	0.25 a	2.53 a	450 a	21.01 a	490 a	20.39 a
± SEM	0.13	0.003	0.18	12.11	0.92	12.51	1.32

Values with the same superscripts within a column are not significantly different; H_0 = sandal tree without host, H_1= sandal tree + *Casuarina*—throughout the experiment, H_2= sandal tree + *Casuarina*—host removed after 6 years; SEM = standard error of the mean

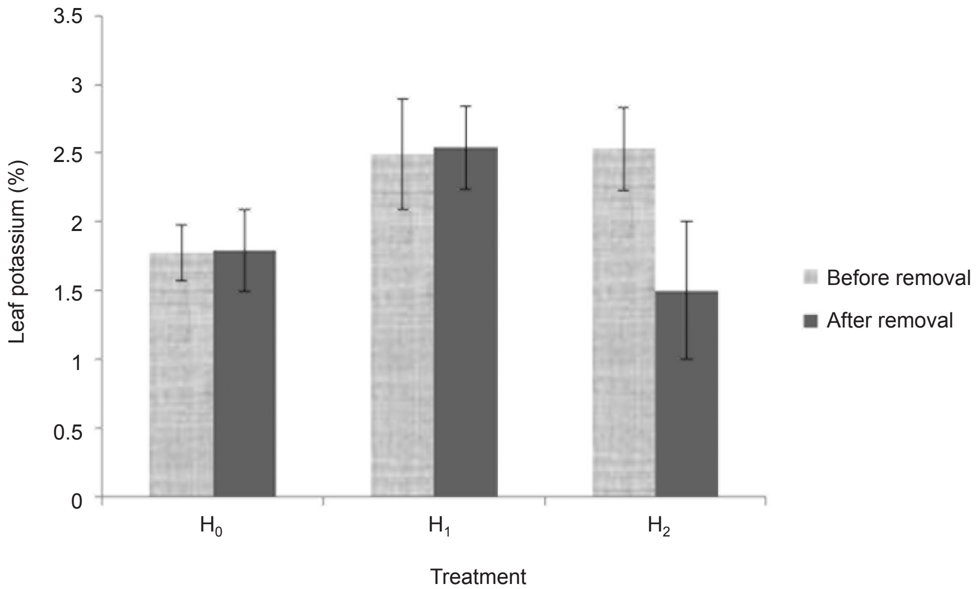


Figure 4 Effect of host *Casuarina* on potassium content of sandal tree leaves before and after removal of host; H_0 = sandal tree without host, H_1 = sandal tree + *Casuarina*—throughout the experiment, H_2 = sandal tree + *Casuarina*—host removed after 6 years

studies were conducted using seedlings. Sandal seedlings with primary host *Alterananthera* had an average of 10–24 haustoria per plant (Luong et al. 2008). Similar results were also reported by Ashokan et al. 2008. In the present study, we observed 44 live and 6 dead haustoria on the *Casuarina* roots when a quarter of 1-m radius and 30-cm depth of the soil was excavated around the sandal tree. More number of functional huastoria was seen attached to the primary root of the host plant. The presence of functional haustoria indicated the possibility of translocation of water and nutrients between host and sandal trees. The haustorial connections were firm and not easily detached during excavation. This may be due to the tissue graft between the host root and the sandal tree haustoria (Figure 5).

The establishment and survival of sandal tree in the field is entirely dependent on other woody plants in its vicinity which serve as hosts. Apart from selecting a suitable host for sandal tree, the possible competitions for aboveground resources such as solar radiation and CO_2 should also be considered. So the best host would be that with more functional haustoria but at the same time offers minimum competition for aboveground resources. Considering the sparse canopy of *Casuarina* with needles and N-fixing nature, it could form an ideal host for sandal tree.

Figure 5 Sandal tree haustoria on *Casuarina* root

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