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Lantana camara as a Potential Secondary host for Natural Populations of *Santalum album* in Foothills of Himalayas: A hope to stand along with Noxious Weed

***Dushyant Sharma*[1] *and Kumari Shiwani*[2*]**

[1]*Assistant Professor, Department of Tree Improvement and Genetic Resources, College of Horticulture and Forestry, Dr. Y.S. Parmar, UHF, Neri, Hamirpur (Himachal Pradesh), India.*

[2]*Scientist, Department of Vegetable Science, College of Horticulture and Forestry, Dr. Y.S. Parmar, UHF, Thunag, Mandi (Himachal Pradesh), India.*

(Corresponding author: Kumari Shiwani)*

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ABSTRACT: Being hemi root parasite, *Santalum album* L. relies greatly on its host for nutrients and water from seedling to maturity, though in the early stages it derives its nutrient requirements from the seed reservoir and soil. Deep rooted perennial hosts help in sustained growth of *S. album*. A field study was conducted in three regions namely, Kangra, Bilaspur and Hamirpur of Himachal Pradesh, India in natural populations of *Santalum album* L. a high valued tree known for its fragrant wood and scented oil, with the aim to confirm and understand its parasitic association with noxious weed species *Lantana camara*. L. Morphological and anatomical studies confirmed the presence of *Santalum album* haustoria parasitizing roots of *Lantana camara* growing in its vicinity. This root association implies that in the absence of preferable, leguminous host species, *Santalum album* successfully parasitize the roots of *Lantana camara* to meet out the nutritional and water requirement for its growth and development. Our study is probably the first to report the dependency and preference of *Santalum album* on *Lantana camara* in foothills of Himalayan region and these findings may have important implications for encouraging plantations of *Santalum album* in areas which are so far invaded by noxious weed *Lantana camara* and where there is no/ minimum possibility of growing any other crop or tree species, to meet out its long-term host/ secondary host requirements for growth and survival which further enhance the Sandalwood production and reduce the pressure on existing natural population.

Keywords: Ecology, host, *Lantana camara* L., root parasitism, *Santalum album* L.

INTRODUCTION

Sandalwood, *Santalum album* L. belongs to the family Santalaceae known for its fragrant wood and scented oil (Rocha *et al*., 2017). It is hemi root parasitic tree partially relying on its host to take water and nutrients (Francis *et al*., 2019). Sandalwood is indigenous to India covering an area of 9600 Km^2 (Gairola *et al*., 2007), mostly grown in states like Karnataka and Tamil Nadu (Kumar *et al.,* 2012, Kausar *et al*., 2014, Rocha *et al*., 2017). Isolated populations of *S. album* grow in various states of India such as Bihar, Gujrat, Haryana, Maharashtra, Madhya Pradesh, Orrisa, Punjab, Rajasthan, Uttar Pradesh, West Bengal, Assam and Himachal Pradesh.

The ecology, growth and host preferences of *S. album* has been well documented (Zhang *et al.,* 2012, Lu *et al*., 2013, Yang *et al*., 2014, Rocha *et al*., 2017, Lu *et al*., 2014, Doddabasawa *et al*., 2020, Doddabasawa and Chittapur 2021). Different researchers have studied the physiology of root parasitism in both pots as well as field/natural populations and observed the interaction between hemi parasitic *S. album* and different host species. The host-dependent physiology of *S. album* in association with N_2-fixing and non N_2-fixing plant species revealed the preference of mixed plantation of *S. album* with *Dalbergia odorifera*, a potential N_2-fixing host species (Lu *et al*., 2014). Further, *S. album* is also specific in choosing compatible host partners. *S. album* is known as parasite of more than 300 species from trees to grasses known to form haustoria (Rocha *et al*., 2017, Nagaveni and Vijayalakshmi 2007). One of the population dynamics studies in *S. album* populations of Himachal Pradesh revealed *Lantana camara* as dominant associated shrub species.

Lantana camara L. is a noxious alien weed belonging to family Verbenaceae. This invasive weed is mostly native to subtropical and tropical America was initially brought to India in 1807 to the National Botanical Garden as an ornamental plant (Kohli *et al*., 2006, Negi *et al*., 2019). *L. camara* is reported to intrude forests of Himalayan Foothills, where it has virtually replaced the

forest floor vegetation and reduced trees growth (Negi and Kandpal 2003). The infestations of *L. camara* are very persistent and have the potential to block succession and displace native species also compete with native colonizers and can interrupt the regeneration process of the other indigenous species. In sub-temperate, sub-tropical and tropical forests this shrub is mainly associated with *Acacia catechu*, *Dalbergia sissoo*, *Pinus roxburghii* and *Tectona grandis* (Ray and Ray 2014). Li (2016) and Teixeira da Silva *et al*. (2016) suggested that along with other tree species like *Acacia auriculiformis*, *Acacia confuse*, *Albizia lebback* and *Cajanaus cajan*, *Lantana camara* can be a suitable host for *S. album* in China. Nevertheless, to the best of our knowledge too little or no information is available to support these findings in Indian context.

Therefore, a survey was conducted in three districts of Himachal Pradesh to find out the parasitism ecology of *S. album* under natural population with shrub weed *L. camara* to address the following questions, 1) Does *S. album* actually parasitize the *L. camara* (host) with specialized absorbing structure called haustorium? and 2) Does the haustoria of *S. album* penetrate host epidermis and cortex establishing a true connection between them? Identifying and understanding the association between both these species would yield important clues on the theoretical and practical significance for encouraging the plantation of economically important *S. album* tree to meet out its long-term host (secondary host) requirement in lands which are so far invaded by *L. camara* and further where there is no/minimum possibility of growing any other crop or tree species.

MATERIALS AND METHODS

The survey was carried out in the year 2021–2022 at three regions namely, Kangra (latitude 31° 41' 00" N and longitude 75° 35' 34" E), Bilaspur (latitude 31°18'00" N and longitude 75°55'00" E) and Hamirpur (latitude 31° 41' 26.8188" N and longitude 76° 31' 3.7740" E), Himachal Pradesh, India where *Santalum album* was recorded as a major tree species growing closely in association with weed shrub species *L. camara* (Fig. 1A and 1 B). These regions fall in sub-tropical, low hill zone of the state distributed along an altitudinal gradient of 500-700 mamsl with average annual rainfall of 1000-1400 mm. The soils of the surveyed area are characterized as slightly acidic having sandy loam to clay loam texture.

The aim of the investigation was to confirm the presence of hautsorial connections between *S. album* and *L. camara* growing together. From all the 3 surveyed sites, 20 mature trees of *S. album* having average girth of 30 cm were randomly selected at a minimum distance of 100 m from each other. Further, 5 mature plants of *L. camara* at a minimum distance of 2 m and maximum 5 m in radius of each selected *S. album* tree were excavated with the help of spade and uprooted for further examination. The haustorial associations present on roots of selected *L. camara* plants were carefully observed and 10 established haustoria on primary, secondary and tertiary roots of each selected host (*L. camara*) along with host roots were harvested for further anatomical examination. Host roots along with haustoria were wash clean of soil and thin microscopic sections (Longitudinal section) were taken out by following standard procedures of fixing. These sections were examined and images were captured using Fluorescent microscope. Figures were assembled using Microsoft Office Publishers.

RESULTS AND DISCUSSION

The established haustoria of *S. album* on *L. camara* roots were observed in all of the regions surveyed (Fig. 1C). The *S. album* haustoria were seen attached to primary, secondary as well as tertiary roots of *L. camara* (Fig. 1, D-F). The presence of haustoria in the host roots indicated the possibility of translocation of water and nutrients from *L. camara* to *S. album.* The average number of haustoria host^{-1} roots were recorded in the range of 50–100. Maximum number of haustoria were recorded in tertiary roots as compared to the primary and secondary roots. This may be due to the fact that main root playing comparatively lesser role in the absorption of water and nutrients in plants (Daddabasawa and Chittapur 2021). Newly initiated haustoria of *S. album* were bell-shaped, tapering proximally by a narrow stalk joining onto its parent root. When the initial haustoria come in contact with compatible host roots they flatten against the surface and initiate the transition into the young haustoria.

For the first time we investigated the anatomy of *S. album* haustoria attached to roots of noxious weed *L. camara* and noticed the close vascular connection between both the species. Following attachment to *L. camara* host roots, intrusive cells of haustoria penetrate the host epidermis and cortex between host cells (Fig. 1, G and H).

Similar observations on association between parasite and host plant species have been reported for Orbanche (Lane *et al*., 1991) and Striga (Losner-Goshen *et al*., 1998). Anatomical section of *S. album* haustorium consisted of two regions, one external to the host root, the hyaline body, a structure with high metabolic activity and the penetrating peg, that makes the initial contact with the host roots and penetrate the host tissue. Following the initial haustorial penetration and upon reaching the host root cambium, the penetration peg flattened out laterally to form a thin ellipsoidal disc (Fig. 2). These observations are in conformity to the findings of Tennakoon and Cameron (2006), who investigated the morphology and anatomy of haustoria formed by *S. album* attached to one of its principal hosts *Tithonia diversifolia*.

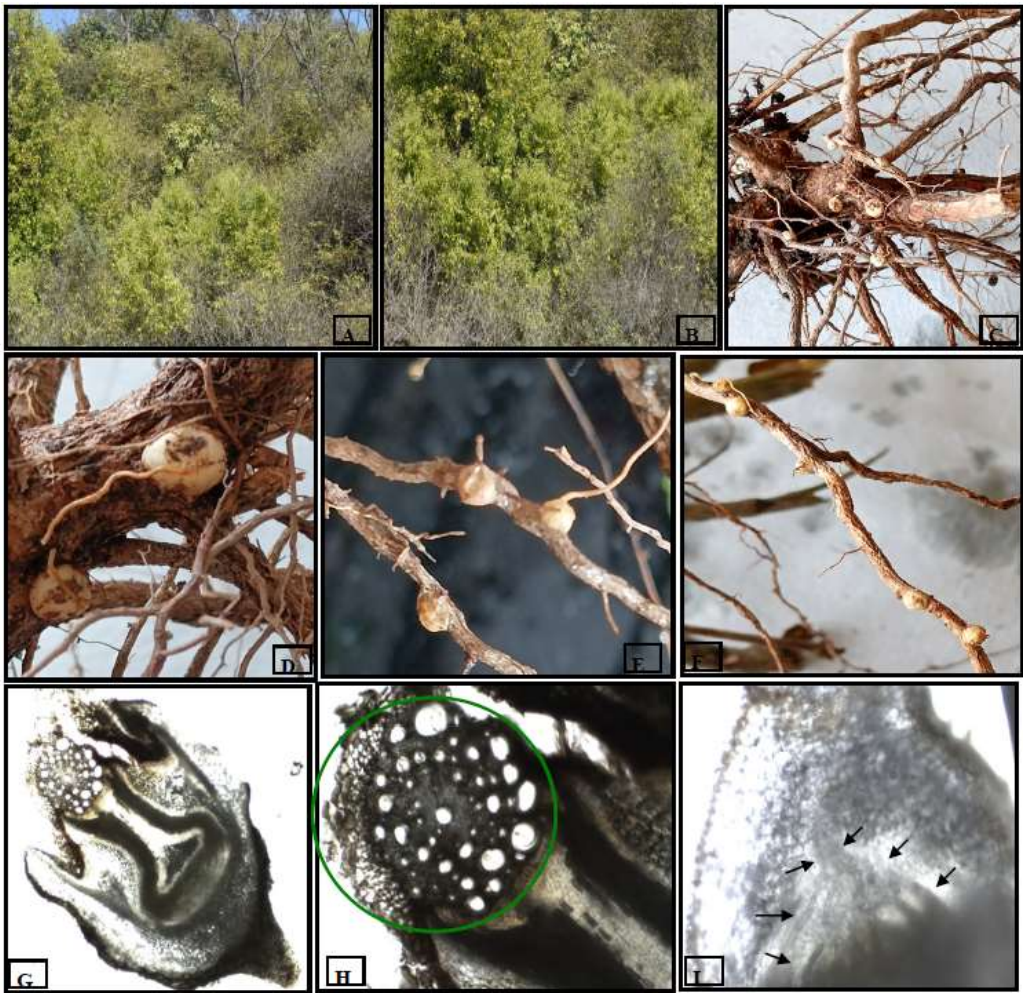

Fig. 1. A. Natural population of *Santalum album* and *Lantana camara.* B. Closure association of both the plants species in natural population. C. Whole Root of *L. camara* with haustoria of *S. album.* D. Haustoria on primary roots of *L. camara* E. Haustoria on Secondary roots of *L. camara* F. Haustoria on Tertiary roots of *L. camara* G. Longitudinal section of *S. album* haustorium with host *L. camara* (10x) H. Vascular bundles of host *L. camara* (40x) I. Finger like projections of haustorium (*S. album*) entering vascular bundle of host (*L. camara*) (100x).

The parasitic nature of *S. album* and formation of haustoria in different host species have been reported by various researchers (Rocha *et al*., 2017, Lu *et al*., 2014, Doddabasawa and Chittapur 2021, Rocha *et al*., 2014). However, most parasitic and physiological studies were conducted on nitrogen fixing and non-nitrogen fixing plant species like *Cajanus* cajan (Nagaveni and Vijayalakshmi, 2003), economical horticultural crops like *Mangifera indica* and *Phyllanthus emblica* (Viswanath *et al*., 2014) and *Citrus aurantium* (Singh *et al*., 2014).

Intimate vascular connectivity between *S. album* and roots of other host species was earlier observed and reported (Rocha *et al*., 2017, Tennakoon and Cameron, 2006), which revealed the absence of direct lumen-to-lumen xylem connection between xylem of hosts and *S. album*. This confirms that movement of xylem sap from the host to parasite occurs principally via pits of host xylem elements.

Similar findings were observed in *S. album* haustoria and *L. camara* roots in our studies (Fig. 1, I). Further, functional status of the haustorial connection between *L. camara* and *S. album* by radio-labelling the host (*L. camara*) are required to confirm this observation.

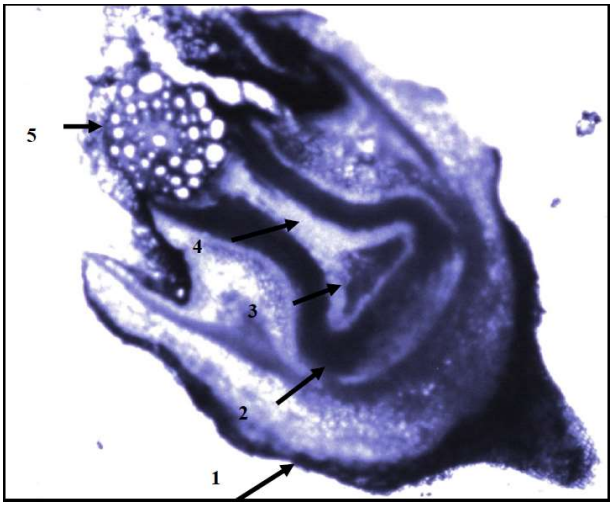

Fig. 2. Longitudinal section (LS) showing various parts of haustorium (*Santalum album)* and host (*Lantana camara*) (10x): 1. Parasitic root of *S. album* 2. Haustorium of *S. album* 3. Hyaline body 4. Penetration peg 5. Vascular bundle of *L. camara.*

CONCLUSION

We identified the parasitic association of *S. album* on roots of *L. camara* which implies that in the absence of reported preferable host species, *S. album* successfully parasitize the *L. camara* with its functional haustoria thereby, trying to meet the nutritional and water requirement. Further this acted as long term secondary host for the better survival and growth of the tree. So, it is suggested to encourage the plantation of economically important *S. album* in the areas which are already invaded by *L. camara* and where there is no/ minimum possibility of growing any other crop or tree species, to meet out its long-term host/ secondary host requirements for growth and survival.

FUTURE SCOPE

Extensive studies on the functional status of haustoria in association with *L. camara* to indicate the translocations from the host to parasite and reverse along with direct and indirect effects of *L. camara* associations as a host on carbon assimilation, plant water potential and nutrient status of *S. album* can be done. Further, studies on allelopathic effects of *L. camara* on seedling recruitment of the *S. album*will be the future thrust areas for appreciation and recommendations of plantation of high valued *S. album* trees in *L. camara* invaded areas.

Author Contributions. Dushyant Sharma and Kumari Shiwani conceived and designed the analysis; Dushyant Sharma collected the data; Dushyant Sharma contributed data or analysis tools; Dushyant Sharma performed the analysis; Kumari Shiwani wrote the paper.

Conflict of Interest. No potential conflict of interest was reported by the author(s).

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