

AN ASSESSMENT ON THE OCCURRENCE OF SPIKE DISEASE IN COMMERCIALY GROWN SANDALWOOD (*SANTALUM ALBUM*) PLANTATIONS IN SRI LANKA

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Abstract:

Santalum album is susceptible to sandal spike, an infectious disease caused by phytoplasma. The disease spreads through phloem feeding insect vectors. As high economic losses are reported due to this disease, the present study was aimed at assessing the status of spike disease in commercially grown sandalwood plantations in Sri Lanka. Specific objectives of the study were to evaluate the distribution, prevalence and severity of the disease in the studied plantations. A survey covering five districts was conducted in 13 commercially grown sandalwood plantations. Total number of plants, total number of affected plants, total number of major branches of the canopy of the affected plants, total number of affected major branches of the selected plants, total number of completely damaged plants, total number of severely damaged plants, total number of moderately damaged plants and total number of lightly damaged plants were counted for each plantation. Survey data were tabulated and analyzed using descriptive methods. The highest prevalence of the spike disease (30.11%) was recorded in Beragala estate and the lowest prevalence (0.36%) was recorded in Mahao 1 estate. In Godigamuwa estate, percentage of completely damaged plants (9.93%) was equal to that of severely damaged plants. In Beragala estate, the majority (39.12%) of the plants were shown to have low damages. Diyuluma and Belihuloya estates were shown to have 39.72% and 75.00% medium damaged plants respectively. In the case of Matale, only low damaged plants were found. Completely damaged plants were not found in Tangalle, Belihuloya, Matale and Mahao estates. The aim of this study is to increase understanding of nature and severity of sandal spike disease among Sri Lankan fields in order to encourage cultivation with resistant on spike disease to discover best management practices. The increased cultivation of sandalwood plantations has significant importance, and it is essential to strengthen the economic ties to overcome current economic crisis.

Key words: phytoplasma; prevalence; sandal spike disease; *santalum album*; severity.

INTRODUCTION

Sandalwood (*Santalum album*) is an evergreen, perennial and semi parasitic tree belongs to the family Santalaceae (Bunney et al. 2023). Genus *Santalum* includes around 18 sandalwood species (Subasinghe 2022). *Santalum album* is native to India, Indonesia, Australia and Sri Lanka (Pullaiah and Swamy 2021). Also it is found in Malaysia, Cambodia, Vietnam, Myanmar, Thailand, Philippines, New Zealand and China. In Sri Lanka, sandalwood is reported in the districts of Badulla, Nuwara Eliya, Ratnapura and Kandy which belong to the intermediate and wet climatic zones (Tah 2021). It is mainly grown in woodland and lowland tropical forests (Ota et al. 2022). Sandalwood is one of the most valuable commercial tree species which in fact is the second most expensive wood in the world (Kucharska et al. 2021).

Sandalwood plant is connected to a host through root haustoria through which it absorbs nitrogen, phosphorous, potassium, magnesium, calcium, iron, amino acids and water. Sandalwood trees are reported to produce an annual increment of 1kg of heartwood per year per tree when trees grow well (Ramulu 2021). The most important part of the sandalwood is oil and the prices of them are determined by the quality (Choudhary and Chaudhary 2021). Sandalwood is widely used in perfumery, cosmetics and medicinal industries (Brown et al. 2022).

S. album is susceptible to sandalwood spike disease (SSD), a communicable disease caused by phytoplasma (Das et al. 2021). The disease is reported during any growth stage of sandalwood plant (Sundararaj et al. 2022). Spike disease can be found in the host plants of sandalwood also. It can be identified only after completely affected by phytoplasma. Phytoplasma mainly spreads through phloem

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feeding insect vectors in the families of Cicadellidae (leafhoppers), Psyllidae (psyllids), and the superfamily Fulgoroidea (plant hoppers) (Ashwini et al. 2022).

The infected sandalwood plants are shown to display typical symptoms of sandal spike disease such as chlorosis, a reduction in leaf size with a rosette appearance and shortened internodes, causing leaves to become crowded on twigs with a bush appearance and as stems stand out stiffly resulting in spike-like appearance (Selvaraj et al. 2022). Leaves and branches dry out (Das et al. 2021). The affected plants do not bear flowers or fruits (Jacob 2022). At the advanced stages, an abnormal erect growth is reported with sprouting of normally dormant buds. The symptoms gradually spread over the entire tree (Arunkumar et al. 2022).

The annual production of sandalwood in India is reported to be reduced significantly due to the spike disease (Das and Pullaiah 2021) where 1 to 5% plant death is reported annually due to the disease. Spike disease is controlled by usage of tissue culture to create the development of insect resistant plants (Mondal et al. 2020). Use of clean propagating materials, vector control and weed management also important. The most effective methods to eliminate sandal spike disease are uprooted of all the infected plants and preventing any growth of sandal spike hosts (Selvaraj et al. 2022). Phytoplasma-based disease can be controlled by the application of plant growth- promoting microbes which provide protection against microbial and insect vectors as well as enhance the nutrient levels (Bapat 2021).

Phytoplasmas are single celled, pleomorphic shaped and cell wall-less prokaryotes in plant phloem tissue. They are unable to grow on culture media due to its obligate nature of parasitism (Das 2021). Phytoplasma is detected by transmission electron microscopy (TEM), light microscopy, DNA-specific-6-diaminido-2-phenylindole (DAPI) fluorescence microscopy technique, enzyme-linked immunosorbent assay (ELISA) and nested polymerase chain reaction (PCR) assay (Gowda et al. 2022). Globally, phytoplasmas are reported to cause more than 300 plant diseases damaging over 700 plant species (Kirdat et al. 2022).

Sandal spike disease have resulted in severe exploitation, pushing *S. album* into the vulnerable class of the International Union for Conservation of Nature (IUCN) Red List (Kumar et al. 2022). Spike disease has caused to remove millions of trees in India. Sandalwood trees in the forests of India became significantly depleted due to spike disease. After the appearance of visible symptoms diseased, trees die within 1 to 2 years (Kumar et al. 2022). Spike disease incidence has not yet been fully reported in Sri Lanka though symptoms are appeared in commercially grown plantations. This study was done to assess the occurrence of spike disease in commercially grown sandalwood plantations in Sri Lanka to find out the severity of the disease.

MATERIALS AND METHODS

Experimental Sites

Representing five districts, Tangalle, Godigamuwa, Moratuwawala 1, Moratuwawala 2, Beragala, Diyaluma, Belihuloya, Matale 1&2, Matale 3, Mahao 1, Mahao 2, Mahao 3 and Mahao 4 plantations belong to Sadaharitha Plantations (Pvt) Ltd were selected for the study which covers a total land area of about 700 acres (Fig. 1).

Data Collection

The affected plants were identified with the known symptoms and characteristics of the disease. All the trees of typical symptoms of sandal spike disease were carefully observed for assessing the prevalence and severity of disease. Generally, the disease affected trees bear shortened internodes, a reduction of leaf size with a rosette appearance, spike like appearance, branches dry out and sprouting of normally dormant buds. Meanwhile the healthy trees bear normal flowers and fruits, leaves oval to lanceolate, olive green in color and shining, no trace of spiked leaves and no drying or defoliation of branches. A survey was conducted from July to September 2022 to assess the prevalence and severity of sandal spike disease across the commercially grown sandalwood plantations in Sri Lanka. The study which covers a total land area of about 700 acres with 150 000 plants. Visual assessment is often the initial step, where trained experts observe the trees for symptoms such as wilting, discoloration, lesions, or other visible signs of disease. Laboratory testing might be conducted to confirm the presence of a specific pathogen or to study the disease's characteristics in more detail. The accuracy of the assessment method relies on the expertise of the assessors, the reliability of the symptoms, the rigor of the laboratory tests conducted, and the overall scientific validation of the methodology used. It's crucial to have a standardized and validated approach to ensure accuracy in disease prevalence assessment.



Fig. 1.
Distribution map of sandalwood plantations in Sri Lanka.

Identification of prevalence and severity of the disease

The study which covers a total land area of about 700 acres with 150 000 plants.

- Total number of plants per plantation - The total number of healthy and disease affected sandal trees were counted separately for each plantation.
- Total number of affected plants per plantation - The total number of infected sandal spike disease trees were counted separately for each plantation.
- Total number of major branches of the canopy of the affected plants - The total number of major branches of the affected plants were counted separately for each plantation.
- Total number of affected major branches (based on visual observations of the known symptoms) of the selected plants - The total number of affected major branches of the selected plants were counted separately for each plantation.
- Total number of completely damaged trees per plantation - Total number of completely damaged trees were counted separately for each plantation.
- Total number of severely damaged trees per plantation - Total number of severely damaged trees were counted separately for each plantation.
- Total number of moderately damaged trees per plantation - Total number of moderately damaged trees were counted separately for each plantation.
- Total number of lightly damaged trees per plantation - Total number of lightly damaged trees were counted separately for each plantation.

Disease severity

Disease severity was expressed as a percentage of the branches affected by the disease to the total branches.

$$\text{Severity (\%)} = \frac{\text{Total number of affected branches}}{\text{Total number of branches}} \times 100$$

Accordingly, disease severity was broadly classified into four groups.

- Completely damaged (More than 75%) - If the severity percentage is between 76-100, the plants were considered as completely damaged trees.
- Severely damaged (50% - 75%) - If the severity percentage is between 50-75, the plants were considered as severely damaged trees.
- Moderately damaged (25% - 49%) - If the severity percentage is between 25-49, the plants were considered as moderately damaged trees.
- Lightly damaged (Less than 25%) - If the severity percentage is between 0-24 the plants were considered as lightly damaged trees. Then following data counted.

Disease Prevalence

The prevalence of the disease was calculated by dividing the number of affected plants at the time of count by the number of individuals examined.

$$\text{Prevalence (\%)} = \frac{\text{Total number of affected plants}}{\text{Total number of plants}} \times 100$$

Data Analysis

Survey data were tabulated and analyzed using excel according to descriptive methods. Bar charts and tables were used as appropriate to elaborate the results.

RESULTS AND DISCUSSION

Disease Prevalence

According to the Fig. 2, the highest prevalence of the spike disease (30.11%) was recorded in Beragala estate which might be due to favorable climatic conditions for the insect vectors enabling them to rapidly spread the disease. The lowest prevalence of the spike disease (0.36%) was recorded in Mahao 1.

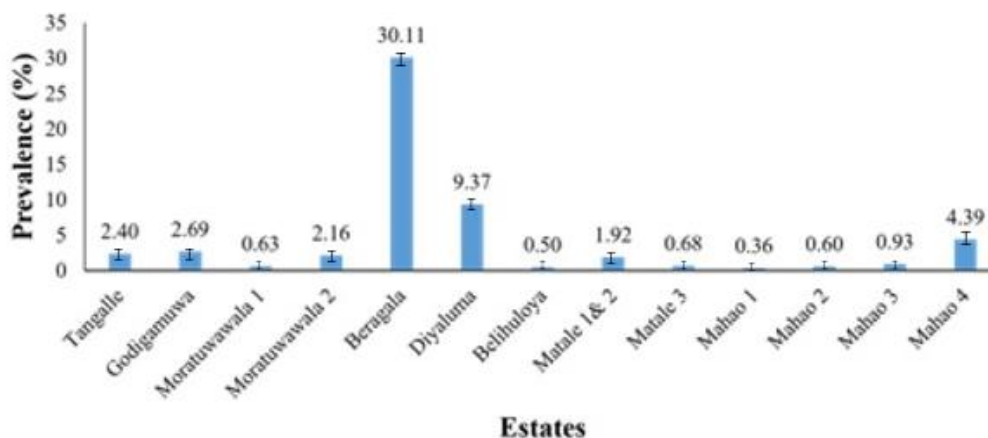


Fig. 2.
Prevalence of the sandal spike disease in sandalwood estates.

Disease Severity

Table 1

Plantation	Levels of damage on Sandalwood severity			
	Level of Damage (%)			
	Fully Damage 76-100	High Damage 50-75	Medium Damage 25-49	Low Damage 0-24
Godigamuwa	10.0	10.0	50.0	30.0
Moratuwawala 1	9.5	4.7	33.4	52.4
Moratuwawala 2	4.0	5.6	9.6	80.8
Beragala	0.3	30.1	30.5	39.1
Diyaluma	0.3	28.5	39.7	31.3

Belihuloya	0.0	0.0	75.0	25.0
Matale 1 & 2	0.0	0.0	0.0	100.0
Matale 3	0.0	0.0	0.0	100.0
Mahao 1	0.0	16.0	360	48.0
Mahao 2	0.0	14.4	19.0	66.6
Mahao 3	0.0	7.1	35.7	57.2
Mahao 4	0.0	2.4	6.6	91.0

According to the Table 1, 50.0% of affected plants were shown to have medium damages and found 10% of completely damaged plants were observed in the Godigamuwa plantation sector. In Beragala estate, favorable climatic conditions for not only the phytoplasma, but also plant host and insect vectors, as well as the interactions between or among these organisms. The Beragala estate is found to have 0.25% of completely damaged plants and 30.1% High Damage plants. Lack of alternative host and relatively unfavorable climatic conditions for the vectors might be the reasons the low damages. In Matale 1 & 2 estates, cooler conditions lower the multiplication of phytoplasma in plants. Completely, severely and moderately damaged trees were not found in Matale 1 & 2 plantations. Same conditions were found in Matale 3 estate as well.

Insect vectors are able to complete the life cycle due to the favorable climatic conditions and thereby spread of the disease. High population of insect vectors is important for increase the prevalence of disease. The higher consumption of the carbon source may affect the growth rate of the phytoplasma and may also directly or indirectly produce severe symptoms. Low phytoplasma nutrient uptake from host plant phloem may be targeted to reduce phytoplasma multiplication and symptom expression in the host (Bertaccini and Duduk 2009). Climate change can affect not only the phytoplasma but also insect vector and plant host as well as the interactions between or among these organisms. Phytoplasma multiplication was faster under warmer conditions in plants and under cooler conditions in insect vectors. The effect of environmental conditions on phytoplasma multiplication is host dependent (Galetto et al. 2011). High temperatures slightly decreased the spread of phytoplasma (Zamorzaeva et al. 2019).

Sandal spike disease has been a main topic for at least 100 years in India. Over a million trees having been removed from Mysore and Coorg states during 1903-1916, due to the disease. Trees in the forests of India became significantly depleted (Silva et al. 2016). High economic losses are occurred in sandalwood due to loss of 1 to 5% plants per every year. In India, the annual production of sandalwood significantly reduced from 4000 tonnes to 1044 tonnes in 1965 to 1995, due to the disease (Murali et al. 2019). Sandal spike disease has leading to a global shortage of sandalwood-based products (Kirdat et al. 2022). Spike disease kills even very young naturally regenerating trees before reaching the age of heartwood formation (Sundararaj et al. 2022).

Sandal spike disease is a communicable disease which can be identified only after completely affected by phytoplasma. After the appearance of symptoms, sandal spike disease affected plants generally die within 1 to 2 years (Silva et al. 2016). Spike disease can infect sandalwood during any stage of its growth. It can be affected to the host plants of sandalwood. Preventive measures applied at initial stages of plant can manage the disease successfully. The presence of phytoplasmas low concentrations in phloem tissues and the uneven distribution of them in infected plants are the main limitations of detection techniques. Phytoplasmas are nonculturable and they are resistant to many antibiotics (Selvaraj et al. 2022).

CONCLUSIONS

The highest prevalence of the spike disease (30.11%) was recorded in Beragala estate. The lowest prevalence of the spike disease (0.36%) was recorded in Mahao 1 estate. Matale plantations were recorded to have only low damaged trees. Completely damaged trees were not found in Tangalle, Belihuloya, Matale and Maho plantations in Sri Lanka. Several sustainable approaches can be taken to eliminate the fictitious Sandalwood Spike Disease and rebuild the important sandal forest. To stop the disease from spreading, rigorous quarantine measures must be put in place first. This can entail limiting the movement of contaminated plant material and doing extensive inspections. Second, encouraging different planting methods and the development of disease-resistant sandalwood cultivars would aid in the regeneration of the forest with hardy trees. Raising awareness of disease management and sustainable agriculture practices among farmers, foresters, and local people can also play a vital influence. To create integrated disease control methods and promote long-term forest regeneration efforts, cooperation between researchers, policymakers, and stakeholders is essential.

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