

Review Article

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Bio Management of Wilting of a Valuable Timber and Medicinal Plant of Shisham (*Dalbergia sissoo* Roxb.) - A Review

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ABSTRACT

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Shisham is a medium to large deciduous (annually shedding the leaves) tree, native to India. It has a light crown and reproduces through seeds and suckers. The *sissoo* is best known internationally as a premier timber species of the rosewood genus. However, *sissoo* is also an important tree used for screen from direct sun light, provides cover or protection and feed for livestock. This lists the medicinal values of *Dalbergia sissoo* DC. (Fabaceae) for various ailments. The wood and bark of *Sissoo* have anthelmintic, antipyretic, expectorant, aphrodisiac abortifacient and refrigerant properties. Oil obtained from the seeds is used to cure diseases affecting skin. Like all other legumes it enhances the quality of soil due to presence of nitrogen fixing bacteria in roots. The leaves falling from the tree are also helpful in improvement of soil quality. It has been found showing severe wilting. The symptoms observed in all wilted plants are: yellowing and death of leaves in acropetal succession and lastly entire plant turns yellow. Pathogenicity test results revealed that both *Fusarium solani* and *Fusarium oxysporum* alone or either are highly potent causing severe wilting in plants. The article covers the chemical synthetic fungicides and biological control of *Fusarium*. This also deals about potential of *Putranjiva roxburghii* having volatile antifungal activity. The oil of *Putranjiva roxburghii* showed complete mycelial inhibition of both test fungi *Fusarium oxysporum* and *Fusarium solani* at 500ppm. The antifungal activity of oil was found thermostable even after autoclaving and storage (upto 120 days). The bark and root extract of *Putranjiva* was also found to be effective against both species of *Fusarium*. In this way this plant has an overall promise for control of *Fusarium*.

Introduction

Dalbergia sissoo (Indian Rosewood) is a deciduous tree, commonly known as *sissoo*, *sheesham*, *tahli*, *Taland* also *Irugudujava*. Tewari (1994) stated that it is native to the Indian Subcontinent and

Southern Iran and also found in tropical to subtropical Africa and Asia. Troup (1921) mentioned that, it is very likely that *sissoo* is indigenous only to the sub-Himalayan tract and has been introduced by man

elsewhere. In Persian, it is called Jag. It is the state tree of Punjab state both in India and the Pakistan. It is primarily found growing along river banks below 900 metres (3,000 ft) elevation, but can range naturally up to 1,300 m (4,300 ft). The temperature in its native range averages 10–40 °C (50–104 °F), but varies from just below chilling to nearly 50 °C (122 °F). It can withstand a long period of abnormally low rainfall, especially one that adversely affects growing or living conditions of 3–4 months and average annual rainfall up to 2,000 millimetres (79 in). Shisham can grow in soils from pure sand and gravel to rich alluvium of river banks in slightly saline soils. Shisham is an important timber wood for furniture fuel, screen for direct sun light, provides cover or protection and feed for live stock. It usually cultivated in forest department plantations and along the man-made strip of water used for irrigation (canals), roadsides, railway lines, water channels and borders of the agricultural lands..

Review of literature highlights that wilt disease is caused by *Fusarium solani* (Mart) Wr. *F.dalbergiae* (Bagchee, 1945; Bakshi, 1954; Bakshi and Singh 1954,1959). Browne (1968) stated serious wilt of sissoo seedlings in nurseries caused by *Fusarium oxysporum* from Pakistan.

From time to time forest pathologists and other researchers viz., Bakshi, 1954, Khan, 2000, Zakaullah, 1999, Khan and Khan, 2000) reported a number of diseases like powdery mildew, leaf rust, leaf blight, collar rot, wilting, die-back and Ganoderma root rot infections in shisham. Khan and Khan (2000) mentioned that *Polyporus* and *Fusarium oxysporum* cause root rot and wilting respectively. *Fusarium solani* was isolated as a facultative parasite associated with wounds and on hosts weakened by unfavorable conditions. This disease has

reached epidemic proportion in Bangladesh and other countries of South Asia. The heart wood of plant is strong and durable and have high timber quality so it needs protection. Bakshi (1955) highlighted that elimination of pathogen from soil is not possible either chemically or by crop rotation. Synthetic pesticides pose a range of risks to human health and protection. There are three types of harmful effects caused by pesticides: acute effects, delayed effects, and allergic effects.

Acute effects are injuries or illnesses that appear immediately after exposure. The effects are usually obvious and capable of returning to an original condition if appropriate medical care is given right away. Delayed effects are illnesses or injuries that do not appear immediately. these include cancer. There are over 160 synthetic pesticides that are listed to be possible carcinogens. Many of these pesticides are still in use. The US EPA has classification systems that identify carcinogens. Pesticides have been known to cause asthma, breast cancer, leukemia, lymphoma and other immune system disorders.

Allergic effects are harmful effects that some but not all people develop in reaction to substances. These are responsible for environmental pollution. Biocontrol agents have been tried but they have their own limits. In nature plants are available which have broad spectrum antifungal and volatile activity that can completely suppress wilt causing fungal pathogens. Now a days, essential oil and their components are gaining increasing interest because of relatively safe status, their wide acceptance by consumers and their exploitation for potential multipurpose functional use (Ormancey *et al.*, 2001; Sawamura, 2000; Tripathi and Kumar, 2007).

The article deals the botanical description, systematic position, distribution, medicinal uses and highlights the work done on causal organism of shisham wilt and its possible management and the integrated strategies that can be used for the management of shisham plants. This also indicates the potential of putranjiva in mixed plantation in field for protection of shisham from wilt.

Botany of Shisham

Plant Description

This is a medium to large deciduous tree with a light crown which reproduces by seeds and suckers. It can grow up to a maximum of 25 m (82 ft) in height and 2 to 3 m (6 ft 7 in to 9 ft 10 in) in diam. Trunks often got crooked when grown in the open. Leaves leathery, alternate, pinnately compound and about 15 cm (5.9 in) long. Flowers whitish to pink, fragrant, nearly sessile, up to 1.5 cm (0.59 in) long and in dense clusters 5–10 cm (2.0–3.9 in) in length. Pods oblong, flat, thin, strap-like 4–8 cm (1.6–3.1 in) long, 1 cm (0.39 in) wide and light brown. They contain 1–5 a smooth kidney-shaped seed, flattened at the sides, 8–10 mm (0.31–0.39 in) long. Sissoo has a long taproot and numerous surface roots which produce suckers. Young shoots drooping and downy; have established stems with light brown to dark gray bark to 2.5 cm (0.98 in) thick, shed in narrow strips; large upper branches support a spreading crown (Figure 1,2).

Taxonomy

Kingdom – Plantae; Unranked – Angiosperma; Unranked Ecidicots; Unranked – Rosids; Order – Fabales; Family – Fabaceae; Sub Family – Faboideae; Tribe – Dalbergia; Genus – Dalbergia; Species – Sissoo.

Vernacular Names

Sanskrit: Aguru, Shinshapa; Bengali: Shisu, Shishu, Sisu; English: Bombay Blackwood, Sissoo, Indian Rosewood, Sisso; Hindi: Agar, Biridi, Tali, Gette, Kara, Shisham, Sisam, Sissai, Sissu, Sissoo; Tamil: Sisutti, Sisso, Nukkukattai, Yette, Gette Thai: Du-Khaek, Pradu-Khaek; Arabic: Dalbergia, Sissoo; Indonesian: Pradu-Khaek, DuKhaek; Javanese: Sonowaseso; Nepali: Sissau, Sisham; Spanish: Sisu; Trade name: Sissoo, Shisham

Geographical Distribution and Suitable Conditions

Distribution: *Dalbergia sissoo* Roxb. (Shisham) is native to the plains, low hills and mountain valleys of the sub-Himalayan region. It occurs naturally from sea level up to 1000 m msl sometimes even up to 1500 m msl, from the river Kabul in Afghanistan through northern Pakistan, northern India, Nepal, Bhutan and Bangla Desh and commonly planted throughout entire India, Pakistan and the Terai region of Nepal. It was successfully introduced to other parts of the Asian subcontinent as well as Southeast Asia, Africa, the Middle East, the Caribbean, North America, and Florida and Arizona in the United States.

Suitable conditions: It occurs naturally in riverine environments where sunlight and moisture are plentiful with annual rainfall averaging 500 to 4500 mm. Temperature in native range varies from 4° to 50°C and it is tolerant of light frosts but killed by low temperatures or long freezes. It grows well on rich alluvial soil, pure sand or gravel conditions with plentiful moisture and good drainage. It requires a pH of 5.0 to 7.7 and tolerates some salinity, but growth is stunted on heavy clayey soils. Natural regeneration is also common on newly exposed sites such

as embankments, landslides, overgrazed areas and abandoned farmland.

Propagation

Propagation takes place most commonly by root suckers and also by seeds. The seeds remain viable only for a few months. Seeds should be soaked in water for 48 hours before sowing and 60% – 80% germination can be expected in 1–3 weeks. Seedlings require partial sun or full sun.

Chemical Constituents

Following chemicals are isolated from various parts.

Leaves-Isoflavone-O-glycoside; Flowers-Biochenin A, tectorigenin and 7-O-methyl tectorigenin; Green pods-Mesoinisitol, 7-O-methyl tectorigenin and 4'-rhamnoglucoside; Mature pods-Isocaviumin, tectorigenin, dalbergin, caviuin and tannins; Stem bark-Dalberginone, dalbergin, methyl dalbergin and dalbergichromene; Heartwood-Dalbergin, nordalberginones, dalbergichromene, fixed oil and essential oils

Uses of Shisham

General

As timber: Shisham is best known internationally as a premier building/furniture timber species, but is also used as fuel wood and for shade and shelter from sunlight. With due tolerance of light frosts and long dry seasons, this species deserves higher consideration for tree farming, reforestation and agro forestry applications. It is the most important cultivated timber tree of Bihar after teak, which is the largest producer of shisham timber in India. In Bihar, the tree is planted

on roadsides, along canals and as a shade tree. It is also commonly planted in southern Indian cities like Bangalore as a street tree.

Shisham is usually dried up before being used in furniture manufacturing. Locally Shisham is seasoned by keeping the logs for 6 month in wide open areas to dry up under the sun.. With hot air circulations it is dried for about 7 days to 15 days depending on weather conditions for commercial applicatons. Shisham is among the finest cabinet and veneer timbers and useful in preparation of 'Kartaals', the Rajasthani percussion instrument. This is also used for plywood, agricultural tools, carvings, boats, skis, flooring, etc.The heartwood is golden to dark brown; the sapwood, white to pale brownish white. Heartwood is extremely durable (the specific gravity is 0.7 – 0.8) and is resistant to dry-wood termites; but the sapwood is readily attacked by fungi and borers. Mukherjee *et al*(1971) mentioned that *Dalbergia sissoo* contains the neoflavonoid dalbergichromene in its stem-bark and heartwood.

For fuel : The calorific value of both the sapwood and heartwood is 'excellent', being reported to be 4,908 kcal/kg and 5,181 kcal/kg respectively. Also makes good quality charcoal for heating and cooking.

For brushing teeth: Traditionally, slender twigs (called datun) are first chewed as a toothbrush and then split as a tongue cleaner. This practise has been in use in India, Africa, and the Middle East for centuries. It has been found that India's 80% rural population still start their day with the chewing stick. Shisham twigs are still collected and sold in markets for this use and in rural India one often sees youngsters in the towns chewing on Shisham twigs. Bhambal *et al.* (2011) stated that it has been found to be equally effective as a toothbrush

in reducing plaque and gingival inflammation.

Toxic uses

Adenusi and Odaibo (2009) found that ethanolic extract of the fruits of *Dalbergia sissoo* have molluscicide effect against eggs of the freshwater snail *Biomphalaria pfeifferi*. The percentage of dead embryos at the prehatch snail stage decreased while the deaths of embryos at the gastrula/exogastrula stage increased, with increasing concentration of extract. Lethality of the ethanolic extract of *D. sissoo* fruits to embryonated egg masses of *B. pfeifferi* is an added advantage to its potential development for use as a plant molluscicide.

Medicinal uses

In Ayurveda, various parts of Shisham tree are used for treating a variety of diseases (Table 1) such as leaves are used for eye pain, breast swelling, painful urination, gynaecological disorders and bleeding disorders. The paste of leaves mixed with sweet oil is useful in skin excoriation such as scrapping and abrading (Anupama, 2015). Herbs are not always safe. They may negatively affect body in certain conditions. Sissoo tree leaves wood and bark have abortifacient property, which means causing abortion. Therefore it must not be used during pregnancy.

Recent work on medicinal uses

The studies revealed that the tree is anti-inflammatory, antinociceptive/reducing sensitivity to painful stimuli property, anti-diabetic, analgesic and antioxidant properties as follows; Shazia *et al* (2006) surveyed on Indigenous knowledge of folk herbal medicines and it is useful in removing dandruff. Mohammad *et al* (2009)

found Anti-inflammatory activity in ethanolic extract of *Dalbergia sissoo* (Roxb.) bark and concluded that the ethanolic extract of *Dalbergia sissoo* bark at 1000 mg/kg showed the most potent anti-inflammatory activity. Jaspreet *et al* (2012) found analgesic and anti-inflammatory activities of *Dalbergia sissoo* leaf extract. Pankaj *et al* (2010) observed anti-diabetic activity of ethanolic extract of *Dalbergia sissoo* L. leaves and reported 12% more effective in reducing the blood glucose level compared to standard Glibenclamide (also known as glyburide). Neeraj *et al* (2012) also evaluated anti-diabetic activity of *Dalbergia sissoo* against alloxan induced diabetes mellitus in wistar albino rats and observed that ethanolic extract of *Dalbergia sissoo* bark possesses significant anti-diabetic activity. Mallinath *et al* (2010) studied phytochemical and pharmacological properties of ethanol extract of *Dalbergia sissoo* seeds and reported the seeds to have moderate analgesic and remarkable antipyretic activities.

Nitinkumar *et al* (2011) found useful against helminths. Arvinder *et al* (2011) evaluated antioxidant potential of stem bark extract of *Dalbergia sissoo*. and reported chloroform extract possesses marked antioxidant activity, whereas methanolic extract has moderate activity. Mohammad *et al* (2011) reported antinociceptive activity in ethanolic extract of *Dalbergia sissoo* (Roxb.) bark. They reported that (300, 500 and 1000 mg/kg) doses of extract exhibited significant and dose dependent antinociceptive activity possibly due to presence of flavanoids. Harsha *et al* (2012) observed anti-termite activity in heartwood of *Dalbergia sissoo* Roxb. Ex.Dc and concluded that the plant extracts can be used as an alternative for synthetic pesticides for termite control in

buildings. Shisham tree is grown as shade tree for protection against direct sunlight along the roads. It increases quality of soil due to presence of nitrogen fixing bacteria in roots. The leaves falling from the tree are further helpful in improving soil quality/soil fertility.

Wilting of Shisham

Wilting

This refers to the loss of rigidity or flaccidity of non-woody parts of plants. It occurs when the turgor pressure in non-lignified plant cells falls towards zero due to loss or poor water retention in the cells. The loss of water retention by the plant has been found greater when the absorption of water and process of wilting modifies the leaf angle distribution of the plant (or canopy).

Loss of water retention may be due to :

Drought, where the soil moisture drops below conditions most favorable for plant functioning (ii) the temperature reaches to a point where the plant's vascular system can not function and high salinity which causes water to diffuse from the plant cells and induce shrinkage (iii) saturated soil conditions, where roots are unable to obtain sufficient oxygen for set of metabolic reactions and processes that take place in the cells of organisms to convert biochemical energy from nutrients into adenosine triphosphate (ATP), and then release waste products and so are unable to circulate water into the plant; or (iv) bacteria or fungi that become blocked with an accumulation of thick wet matter in the plant's vascular system.

Wilting diminishes the plant's ability to transpire and grow. Permanent wilting leads to plant death. In woody plants, reduced

water availability leads to blockage of the xylem.

Permanent wilting point (PWP) or wilting point (WP) is defined as the minimal point of soil moisture the plant need not to wilt. If moisture reduces to this or any lower point a plant wilts and can no longer recover its turgidity when placed in a saturated atmosphere for 12 hours. The concrete definition of the wilting point (symbolically expressed as θ_{pwp} or θ_{wp}) is defined as the water content at -1500 J/kg of suction pressure, or negative hydraulic head. This is defined as the percentage water content of a soil when the plants growing in that soil are first reduced to a wilted condition from which they cannot recover in approximately saturated atmosphere without the addition of water to the soil (Taiz and Zeiger, 1991).

Symptoms Caused due to Fusarium Infection

The *Fusarium* affects sissoo plants of any age group. *Fusarium* generally produces a condition in which leaves produce insufficient chlorophyll. As chlorophyll is responsible for the green color of leaves and *chlorotic* leaves are pale, yellow, or yellow-white and death of most or all of the cells in an organ or tissue, premature leaf drop, browning of the vascular system. *Fusarium* wilt starts out looking like vein clearing on the younger leaves and drooping of the older lower leaves, preventing them from growing or proper development of the plant, yellowing of the lower leaves, defoliation, marginal death of most or all cells and death of the plant. On older plants, symptoms are found more distinct between the blossoming and fruit maturation stages. (Figure 3,4).

Shisham mortality is spread throughout the Shisham zone, more severe in the Eastern Uttar Pradesh and Bihar in India. It falls

under the category of causing tree decline diseases.

Extent of Damage

Trees of all ages and trunk-diameter classes are affected in the monoculture plantations. Mixed plantations show less signs of mortality. Mature trees of more than 50 years age are highly prone in Shisham plantations. Younger plantations of Shisham show too high % mortality in some areas, particularly where biotic stresses, and erratic rainfall and extreme temperature variations/water-logging have occurred during recent years. Dead trees, partially dead trees as well as stumps that are not removed act as sources of infection.

Factors for Shisham Mortality

Unsuitable site selection is one of the main reasons of shisham decline. It grows well on well drained sites but not well in heavy texture soils (with more clay and silt content and less sand). Improper soil aeration in stiff and clayey soils cause death of fine/feeder roots due to asphyxiation besides water logging, even for a short duration, causes poor aeration and death of fine/feeder roots due to asphyxiation. Root disease pathogens enter through these dead roots (infection courts) and then attack living roots. Extended period of low temperature/freezes expose the trees to disease. The pressures resulting into weakening of tree vigour such as: - Injury to roots in agriculture (in fields) and construction activities (near roads, avenues) - Cleaning and weeding done through harrowing in plantations causing root damage - Covering of basal area with landfill, garbage and other material particularly on roadsides and urban areas - Uncontrolled lopping in agriculture fields - Blazing of bark for numbering of trees (on roadsides) - Injuries by cattle - Intentional

girdling (on roadsides for removal). All these biotic pressures result into opening of wounds, site deterioration and overall weakening of vigour resulting into attack by the pathogens and decline/mortality. Bakshi (1955 and 1957) observed that higher moisture and water logging favoured an higher disease incidence. Irrespective of stress conditions across tree girth, maximum incidence was recorded in trees with 51-100 cm girth followed by 101-150 cm girth. This shows that younger trees were more susceptible to disease than older and higher girth trees. Dayaram *et al*(2003) reported many stress factors such as waterlogging, flooding, semi-flooding, drought, degraded soil, uncared ploughing, high density and high moisture and waterlogging caused 73.1 % disease whereas, high irrigation alone caused 13.8% incidence. Flooding, semi-flooding, degraded soil, uncared ploughing and high density and moisture caused 27.4, 52.1, 27.6, 30.2 and 41.1 % incidence, respectively.

Work Done on Causal Organism and Pathogenicity

The Shisham or Indian Rosewood tree is a much-prized tree, cultivated for its timber. But it is highly susceptible to a disease called wilt caused by fungi which target particular species. Two pathogens have been found responsible for shisham mortality - *Fusarium solani* f. sp. *dalbergiae* causing vascular wilt and *Ganoderma lucidum* causing root rot. The former was found wide spread throughout shisham growing area whereas *G. lucidum* is associated in drier localities such as Haryana and Punjab. Virulent and avirulent strains of *Fusarium solani* f. sp. *dalbergiae* exist. The pathogen moves up the stem from the roots. Parker (1918) investigated that *Fomes lucidum* attacks the roots of living sissou trees and speedily cause their death. The

much more dangerous fungus is *Fomes lucidus* which is responsible for high mortality of sissou trees (Troup 1921). Bakshi (1956) highlighted *Fusarium solani* is responsible for causing wilt and death of sissou. The infection occurs through roots from where the fungus proceeds along the stem to some extent. Khan and Bokhari (1970) reported that the commonest pathogens of sissou is *Fomes lucidum*, a root and heart rot fungus that causes extensive damage once it is established. The other fungi which affect sissou are *Poria ambigua* and *Polyporus gilvus* which cause die-back and canker.

Bakshi (1954) said that Shisham is an important timber species of North India. It has been found to suffer from wilt disease in the Dehra Dun and Saharanpur districts in western Uttar Pradesh. The disease occurs both in natural forests and in taungyas which are artificially regenerated with field crops in admixture with other economic species like semal (*Bombax malabaricum*), babul (*Acacia arabica*), khair (*Acacia catechu*), bamboo (*Dendrocalamus strictus*), etc. Only trees of about 15-25 years old suffer from this disease but wilting has not been observed in the seedling, sapling and pole stages of the plant. The symptoms of wilt in shisham are systemic and are characterized by drooping leaves and branches due to loss of turgor. The leaflets gradually turn, yellow, and eventually drop off. The entire tree becomes 'thin' and light coloured, and stands out sharply in contrast to adjoining densely clothed green healthy trees. The nodules and slender branches on roots which characterize healthy shisham are absent on the roots of wilted trees. On splitting the diseased roots, the bark and the outer sapwood exhibit a well-defined, pinkish-brown, stain, and though the stain is restricted in this region, it may rarely penetrate into the inner sapwood. The

heartwood is free from the stain. The stain also progresses along the outer sapwood from the roots to the stem and, in the late stage of wilt, it may extend up the stem to about ten feet from the ground (Bakshi, 1954).

In the irrigated plantations in Bhagat in Punjab, Khan and Bokhari (1970) reported that nearly 1 tree/acre was found diseased out of the 74 standing trees. The total yield in all the fellings decreased by 21%. In financial terms, the loss was about 31 % of the total expected income. Out of the 8 % of diseased sissou trees, the common pathogens were *Ganoderma lucidum* (7.85%) and *Poria ambigua* (0.45%). The cumulative rate of loss in 20 years came to be more than 28 %. The wilt disease gets manifested during the months of September - November both in India and Bangladesh during humid months from July to September (Sharma *et al.*, 2000; Baksha and Basak, 2000).

Shakir *et al.* (1999) investigated *F. solani* from diseased roots and assumed this organism to be the cause of shisham decline. Baksha and Basak (2000) observed a wide spread mortality of shisham trees of varying ages in Bangladesh and assumed that *F. solani* and shothole borer may be the cause of disease. Earlier, Bakshi (1957) also isolated *F. solani* from diseased shisham plants. The fungal hyphae and jelly like substances plug the vessels resulting in wilt symptoms (Bakshi and Singh, 1959). Davis *et al.* (1953) found that wilt is generally the result of *Fusarium* attack at the roots or even lower portions of stem where its growth interferes with the safe passage of water and excreted toxins. According to some workers, *Fusarium oxysporum* is the cause of shisham wilt (Gill *et al.*, 2001). Dieback is caused by *Phytophthora cinnamomi* (Gill *et al.*, 2001). Some people confuse the wilt with dieback. Dieback is entirely different disease

characterized with thinning of leaves and crown, drying up of the ends of branches, table topped condition and stag-headness in extreme conditions (Khan and Khan, 2000).

Bajwa *et al* (2003) stated that shisham tree has been inflicted with dieback and wilt diseases in the recent years and the %incidence is also reported in Tarai tract of Nepal, believed to be its home. The characteristic symptoms of shisham wilt were yellowing and death of leaves in acropetal succession up the tree, as a result the whole tree appears yellow. In advanced stages the affected trees show signs of wilting, the leaf shed rendering the branches bare, and ultimately plants die within a few months. Older trees are usually found to be more prone to mortality. The outer sapwood shows characteristic pink to reddish stain. Though it is normally restricted to outer sapwood, sometimes it penetrates in the inner sapwood yet, the heartwood is not discoloured. The stain progresses along the outer sapwood of the root to the stem and in later stages of wilting it extends up the stem to about 3-5 m from the ground.

Dayaram *et al* (2003) observed twenty districts of North Bihar to study the extent and causes of shisham mortality. Highest disease incidence was recorded in Araria district (80.0%) followed by Katihar (78.0%). Lowest disease incidence (35.4%) was recorded in Darbhanga followed by Khagaria (41.6%). 60.5% disease was recorded in plants having 51-100 cm girth followed by plants 101-150cm girth (48.7%). Waterlogged condition aggravated the disease incidence. *Fusarium solani* 1. sp. *dalbergiae* has been confirmed as the pathogen. Abiotic stress conditions viz.; waterlogging, flooding, semiflooding, drought, degraded land etc. were also recorded during survey. Plant parts as well as rhizosphere soil samples of infected alive

and dead shisham trees were collected and brought to laboratory for analysis to establish the cause of mortality. Symptoms and per cent incidence were recorded in the field. On the basis of girth the infected trees under all stress conditions were categorised into 0-50, 51-100, 101-150, 151-200, 201-250, 251-300 and 301- 350 cm (circumference at breast height) classes. Rhizosphere soil samples of infected shisham trees were analysed to study any relationship of mortality with the pH & EC. Three types of disease symptoms were noted in naturally wilting trees. Green tree showed sudden wilting tendency with complete leaf drooping and drying from top of tree. After 15-20 days dried leaves fall off from the branches. The branches start drying from the top and the plants dry within 3 months. Sometimes after leaf fall, new small leaves and some new shoots appear but wilting appears again within 3-4 months. Such plants die within 2-3 m after second infection. Slow wilting and yellowing symptoms were observed in upland plantations as compared to low land and waterlogged plantation conditions. First, the green leaves turned yellow and then branches dried down slowly from top to bottom and showed complete drying in 9-12 months. Some times partial wilting of tree occurs and the healthy part remains alive for a longer period. It takes normally 2-3 yr for complete death/drying of plant.

Rukshana and Javaid (2007) observed that in Punjab trees were severely suffering from wilt and dieback diseases. Maximum mortality of up to 80% was observed along the canal bank followed by 20-40% along the highways and roadsides. The least disease incidence and mortality rate was observed in plants growing on agricultural and well managed lands. Generally the older plants were found to be more susceptible to dieback attack than the younger ones.

However, wilt was common both in young and old plants. Stressed conditions either drought or high soil moisture content were found to be helpful for attack of pathogen and severity of the disease. *F. solani* (Mart.) Appel & Wr. was isolated from the roots of shisham plants suffering from wilt disease. Rajput *et al*(2008) isolated *Fusarium solani* from shisham dieback trees. Internal browning of stem and roots were rated on 0-5 scale. Shisham plants inoculated with *F. solani* alone produced maximum disease incidence, showed prominent typical symptoms of the disease with internal browning of stem and roots. However, *R. solani* and *C. lunata* either completely failed or caused very rare infection on test plants. *F. solani* produced moderate infection on shisham seedlings when inoculated with either *R. solani* or *C. lunata*. Maximum reduction in root and shoot length was observed in plants inoculated by injecting spore suspension of *F. solani* as compared to spore suspension added to soil or plants sprayed with spore suspension. Root and shoot weight also decreased when spore suspension of *F. solani* was injected into stem followed by soil amended with spore suspension and plants sprayed with spore suspension. Similar trends were also observed about reduction in whole plant growth and weight. Host range studies conducted by inoculating seedlings each of 10 different trees with *F. solani* indicated that the test fungus was moderate to highly pathogenic to shisham, Indian laburnum, siris and gold mohar.

Bhandari *et al*(2014) mentioned that the genetic diversity in shisham is very low; which is the reason for increased attack by diseases and insect-pests. The species is eclipsed with one of the most important disease called dieback wilt by *F. solani* f. sp. *dalbergiae*. The biotic and abiotic factors help in the spread of pathogen. In the

plantation trial at Hoshiarpur (Punjab) the dieback wilt causes a tremendous damage to the standing trees. Mortality was found highest (7.65%) for the experimental trials of shisham that includes a total of 49 clones and rametes. The disease was spreading rapidly and affecting other healthy plantations in the trial.

Kumar(2014) investigated wilting in North Eastern Uttar Pradesh and his survey registered more than 30% wilted plants. It was found that wilting is highly alarming in Basti district with 50-60% wilting in the month of July followed by Siddharthanagar, Santkabirnagar and Gorakhpur district (Table 2). Wilted plants were observed in all age groups, in nursery, 5-10 year, 10-15 year, 15-20 year, 30-40 year with yellowing and death of leaves in acropetal succession and lastly death of entire plant in humid months from July to September. 16 fungal species were found to be associated with sterilized and unsterilized root pieces. The per cent occurrence of *Fusarium oxysporum* in Basti, Santkabirnagar, Siddharthanagar, Gorakhpur district was found to be 80.4, 80.3, 78.6, 53.6 per cent respectively and that of *Fusarium solani* was 79.4, 79.3, 79.0 and 54.8 per cent respectively. On pathogenicity *F. oxysporum* showed 70% wilting while *F. solani* showed 80% wilting while control set showed no wilting.

Mechanism of Wilting

The production of microconidia takes place in great quantity and may be either oval, elliptical or kidney shaped and produced on any portion of mycelium growing above the nutrient medium as aerial mycelia. Macroconidia (three to five celled), gradually pointed or curved edges and found on sporodochia on the surface of diseased plant (in culture the sporodochia may be sparse or

nonexistent). The Chlamydo-spore formation takes place either singly or in pairs, but can sometimes be found in congregate or in short row. Being thick walled spores they are produced within or terminally on an older mycelium or macroconidia. In comparison to other types, chlamydo-spores can survive in the soil for a long period.

F.oxysporum is a common soil pathogen and saprophyte that feeds on decaying matter composed of organic compounds or the remains of organisms such as plants and animals and their waste products. This fungus flourishes in the soil laden mass of loose mud, sand, *soil*, rock etc as mycelium having all spore types, but mostly the chlamydo-spores. Its spread occurs in two basic ways: to short distances by air moving in a certain direction and also instruments used in plantations and to long distances by infected materials and seeds. *F. oxysporum* invades and proliferates in a healthy plant by means of mass of hyphae or by germinating spores penetrating the root tips, root wounds, or lateral roots extending horizontally to anchor the plant securely into the soil. The overall plant physiology gets inhibited due to mass of hyphae going intracellularly through the root cortex reaching up to xylem. In the xylem, the mass of hyphae remains exclusively in the vessels and produce microconidia which have capacity to enter into the sap stream and get transported upward. Due to the presence of dissolved sugars and minerals in the circulatory system the microconidia germinate. Eventually the vascular vessels become blocked with an accumulation of thick mass of hyphae and spores. This prevents the plant from up-taking and translocating nutrients. Lastly the plant transpires off water vapour through the stomata much more than it can transport and the stomata get closed, the leaves wilt and resultantly the plant dies. The fungus invades

all tissues, sporulates well and continues to infect neighbouring plants.

Management of Wilting

Steps for Control

Khan *et al.* (1965) highlighted that mortality of sissou is the result of physiological problem brought about by soil-cum-irrigation factors. The temperature and wind play an indirect role. Remedial measures suggested were artificial application of more water to the land or soil and changing of plantation make up/maintenance schedule.

Although the cause of die-back problem has not been clearly understood still a number of following remedial measures can be taken to prevent or minimise the disease; Avoid Injury – It was observed that mostly trees grown along water channels got infected as compared to the scattered ones. It was found that during the cleaning water channels, roots of the trees got injured helping easy entry of pathogens. Possibly that frequent inter cultivation also increases the chances of root injury. Which should be restricted after establishment of trees (Khan *et al.* 1965).

Selection and preparation of site – Raise shisham on a site having light textured soil with adequate soil moisture and good drainage. Avoid hard clayey soils with tendency of water logging.; **Mixed Cropping** – When growing two crops intermingled together in the same field, the incidence of infection is usually low. Introduction of resistant plants such as *Acacia nilotica* *Mours* spp., and *Eucalypts* spp is also recommended. Avoid pure plantation of shisham and have them mixed preferably with nonleguminous species.

Sanitary Precautions

The infected stumps must be removed from the ground as they may spread pathogen to healthy trees. In areas used for sissoo planting, all effort must be made to free the ground completely of dead and decayed wooden fragments and fungal fruiting bodies which are ready source of infection. Deep wounds should be covered with grafting wax and rubber latex. This will not only allow the timely utilization of the timber from the dead trees but also check the spread of the pathogen to the adjacent trees.;

Deep Planting

In dry locations deep irrigation is recommended so trees can develop deep root systems which can draw water from the water table when irrigation is stopped. In addition sowing of seeds and a deep planting hole are recommended to help develop long tap root, which may reach capillary zone of sub soil water within 2-4 years. (Khan *et al.* 1965)

Ban on Debarking

Complete ban on debarking should be forced.

Site Selection

Elimination of the pathogen (*F.solani*) from the soil is not possible either chemically or by growing different crops in succession on a piece of land to avoid exhaustion of the soil and to control weeds, diseases and pests. Therefore selection of light textured soil having adequate soil moisture and drainage is important.

Removal of Over-aged Trees

Wilting trees of more than 45 years age should be removed. It will reduce further

spread of infection and also termite problems.

Selection of Resistant Clones and Propagation

– Resistant material has been developed by Forest Research Institute and should preferably be used for future plantations. However, selection of resistance is a continuous process. Bajwa and Javaid (2007) advocated that Resistant shisham varieties should be planted on well drained sandy loam soils to control wilt and dieback. The severely infected and dead plants must be uprooted followed by disinfection of the soil to avoid further spread.

Control Biotic Pressure–The biotic pressure on shisham can be reduced by developing alternate forest area as buffer zone. The extensive village eco-development programme will also help to reduce the biotic pressure. Field staff should also be sent to other plantations to gain first hand information.

Integrated Disease Management

According to present literature the management can be achieved as follows-

Chemical Management

Khan *et al.* (1965) found that carbendazim (Bavistin) and captan (captan) fungicides are very effective against *F.solani*. Ahmad *et al.* (1996) mentioned that among the three fungicides evaluated against *F. solani in vitro*, Benomyl was found to be highly effective causing a significant reduction in mycelial growth even in very low concentration of 10 ppm. Ridomil was effective but at higher concentration. Some other fungicides such as Vitavax, Dithane M-45, Bavistin are also known to have significant suppressive effect on growth of *F. solani*. Benomyl, the most effective fungicide in *in vitro* also proved very

effective *in vivo* and this fungicide may prove highly beneficial to save the shisham trees from wilting. In an experiment all the three shisham plants, which were likely to be dead by wilting during next few weeks, managed to recover themselves from disease after treatment with Benomyl. However, there is need to study its effectiveness against the wilt attack in older trees. Bajwa and Javaid(2007)found that Benomyl was effective in controlling wilt in 6-8 years old shisham plants. It is a stable fungicide suitable for injection into the trees (Mcwain and Gregory, 1973). A benomyl derived fungus toxicant MBC (Methyl-2-benzi midazol carbamate) is also known to be effective against wilting.

Biocontrol Agents;Fungi

Bajwa and Javaid(2007)investigated that Shisham decline can be controlled by adopting integrated disease management (IDM) approach. *Trichoderma harzianum* Rifai, *T. viride* Pers. ex Gray and *T. aureoviride* Rifai can be used as biological control agent to reduce the field inoculum of *F. solani*.

Biocontrol Agents;Bacteria

Czaczyk *et al* (2002) reported the antifungal activity of *Bacillus coagulans* against three pathogenic species of *Fusarium* by checking colony forming units, dry matter and ergosterol level and biosynthesis of *Fusarium* mycotoxins. Estimation of ergosterol level as a determinant of fungal growth showed the greatest degree of *Fusarium* sp. inhibition. Addition of *Bacillus coagulans* to *Fusarium culmorum* culture inhibits the DON (deoxynivalenol) production. Jun Yuan *et al* (2012) found that *Bacillus amyloliquefaciens* NJN-6 produces volatile compounds (VOCs)inhibiting growth and spore germination of *Fusarium*

oxysporum f. sp. cubense. Out of 36 volatile compounds detected, 11 compounds completely inhibited fungal growth. The antifungal activity of these compounds suggests that VOCs can play important roles over short and long distances in the suppression of *F. oxysporum*.The VOCs produced by NJN-6 strongly antagonized *F. oxysporum* in soil and the quantity of *F. oxysporum* in the treated soil was 10^2 g^{-1} after 45 days as against 10^4 g^{-1} in the control soil. Previous research has shown that abundant nutrients in the soil increased the production of bacterial VOCs, suggesting that the amount of organic matter in the soil might affect the ability of NJN-6 to release VOCs into the soil. Nonvolatile antibiotics, including lipopeptides, have strong antifungal activities. However, these nonvolatile antibiotics cannot spread over long distances and only when these antagonists directly colonize the plant roots they can prevent pathogenic fungi from infecting plants. In contrast, VOCs can spread over a long distance and fungistatic microenvironments exist around the antagonist communities. In addition, the antifungal VOCs produced by bacteria can kill surviving spores in the soil and limit both the production, spread and the establishment of the disease.

Management with Broad Spectrum Antifungal Plants

Since *Fusarium* has very wide host range causing wilt in many plants,hence pathologists have often tried for finding antifungal activity in plants to develop ecofriendly management of wilts which is as follows-

Antifungal activity of different concentrations (2, 4, 6 and 8% w/v) of leaf extracts of wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), sunflower (*Helianthus*

annus L.), chilies (*Capsicum annum* L.), onion (*Allium cepa* L.) and marigold (*Tagetes erectus* L.) was evaluated in vitro for checking growth of *F. oxysporum*. Extract of marigold, sunflower and chilies were found highly effective having reduced fungal biomass by 54- 79%, 33-85%, 45-57%, and onion by 73% respectively (Tariq Riaz, *et al.*, 2008). Sharma and Kumar (2009) also tried for the development of ecofriendly antifungal compounds for controlling plant diseases caused by *F.oxysporum* through extracts of three weeds namely *Capparis decidua*, *Lantana camara* and *Tridax procumbens*. The spore germination/spore counting technique was followed for the evaluation of the fungicidal properties of the extracts at three different concentrations. Results revealed that the free flavonoids and sterols of *T. procumbens* (flower) and bound flavonoids of *C. decidua* (fruit and stem) totally inhibited spore germination of the fungi (100%). The antifungal components from these plants could be used in developing novel fungicides (biopesticides). Asha *et al.*(2009) assessed activity of the crude extracts of six plants viz, *Allium sativum*, *Capsicum annum*, *Artimisia vulgaris*, *Eupatorium adenophorum*, *Gaultheria fragrantissima* and *Phyllanthus emblica* against *F. solani* (Mart.) Sacc. The extracts of all the plant species were effective in inhibiting the mycelial growth. Jasenka *et al* (2010) observed potency of essential oils (clove, rosemary, cinnamon leaf, sage, scots pine, neroli, peppermint, aniseed, caraway, lavender, common thyme) for *in vitro* antifungal activity on twelve plant pathogenic fungi (*Fusarium graminearum*, *F. verticillioides*, *F. subglutinans*, *F. oxysporum*, *F. avenaceum*, *Diaporthe helianthi*, *D.phaseolorum* var. *caulivora*, *Phomopsis longicolla*, *P. phaseolorum* var. *caulivora*, *P.longicolla*, *P. viticola*, *Helminthosporium sativum*, *Colletotrichum*

coccodes, *Thanatephorus cucumeris*). The results indicated that all oils except scots pine and neroli had antifungal activity against some or all tested fungi. The best antifungal activity was in common thyme, cinnamon leaf, clove and aniseed oils (Jasenka *et al.*, 2010).

Sirirat (2010) evaluated essential oil of *Trachyspermum ammi* Lin. against three strains of *F.oxysporum*. *F. oxysporum* f.sp. lycopersici, *F.oxysporum* f.sp. cubense and *F. oxysporum* f.sp. capsici the wilt pathogen of tomato, banana and chili respectively. The *in vitro* assay (based on poison food method) indicates that ajowan (*Trachyspermum ammi*) oil, in solution phase, possesses strong antifungal activity against the test fungi. The Minimum Inhibitory Concentration (MIC) and the Minimum Fungicidal Concentration (MFC) were 240 and 480 $\mu\text{g}\cdot\text{mL}^{-1}$, respectively. The antifungal activity of volatile headspace of the essential oil was evaluated under a modified atmosphere in inverted Petriplates. Headspace vapor of ajowan oil has a strong activity with Minimum Inhibitory Quantity (MIQ) and the Minimum Fungicidal Quantity (MFQ) of 12.5 and 25.0 μl , respectively. Additionally, the effects of ajowan oil on the biomass production and sporulation of the test fungi indicate that it has significant retardation effect on the biomass production and sporulation of the fungi. Results suggested that ajowan oil has potential use as a biofungicide against the wilt pathogens.

Al-Hetar *et al.*(2011) investigated the *in vitro* antifungal activity of chitosan against *Fusarium oxysporum* f. sp. cubense Race 4 (FocR4) the causal agent of banana wilt. Chitosan at all concentrations tested reduced the hyphal growth of FocR4 on potato dextrose agar media and registered maximum inhibition of 76.36% at 8 mg/mL.

Table.1.Medicinal uses of Various Parts of Shisham

Plant parts	Preparation	Problem
Leaf	<i>Juice mixed with honey as eye drop</i>	<i>Pain in eyes</i>
	<i>Leaf juice in dose of 10-15ml thrice a day</i>	<i>Jaundice,pus in urine</i>
	<i>50-100ml decoction of leaves,drink twice a day</i>	<i>Painful urination,boils, pimples,blood purification</i>
	<i>Warmed and tied on affected area for reducing swelling</i>	<i>Breast swelling</i>
	<i>10-15 ml juice of leaves twice a day</i>	<i>Pain in abdomen</i>
	<i>Juice in dose of 10-15ml,twice in a day</i>	<i>Abnormal bleeding in females</i>
Bark powder	<i>3-6 grams with one cup milk/water for 2-3 weeks</i>	<i>Body pain</i>
	<i>3-6 gm decoction</i>	<i>Gonorrhoea</i>
	<i>10gm sissoo bark boiled in 500ml of water till the volume reduces to half, mix the juice and consume for 40 days every morning</i>	<i>Leprosy</i>
	<i>Bark powder 1 kg cooked in 2 litre water, taken in dose of ten grams with milk 3 weeks</i>	<i>Sciatica</i>
Shisham oil	<i>Topical application</i>	<i>Skin diseases</i>

Table.2 Percent Wilting of Sissoo Tree in Different Districts of Eastern U.P during July(Kumar,2014)

Name of Place (District/village)	Per cent wilting	Name of Place (District/village)	Per cent wilting	Name of Place (District/village)	Per cent wilting	Name of Place (District/village)	Per cent wilting
Basti		Santkabirnagar		Siddharthanagar		Gorakhpur	
Jamdi Road	51	Sameriwa	30	Dumariaganj	42	Bhiti Road	30
Mahsoo Road	55	Nandor	39	Halore	40	Sahjanwa	31
Sonupar area	60	Lohrauli	30	Itwa tahsil	44	Ghagsara	32
Munderava	50	Mangua Road	39	Bansi	40	Khajani	33
Orwara	54	Khalilabad	38	Naugrah	49	Pipraich	29

Table.3 Evaluation of Essential Oils against *F. Oxysporum* and *F.Solani*(Kumar,2014)

Plant species	% inhibition of mycelia growth of test fungi at 500ppm		
	Family	<i>Fusarium oxysporum</i>	<i>Fusarium solani</i>
<i>Aegle marmelos</i> (L.)Corea	Rutaceae	37.3	62.1
<i>Ageratum conyzoides</i> L.	Asteraceae	70.5	64.2
<i>A. Houstonianum</i> L.	-	80.5	80.5
<i>Anisomeles ovata</i> R.Br.	Lamiaceae	60.3	60.3
<i>Artabotrys hexpetalous</i> (Lamm)Merr.	Annonaceae	54.2	46.7
<i>Feronia elephantum</i> Correa	Rutaceae	59.7	60.3
<i>F.limonia</i> (L.) Swingle	-	60.8	65.4
<i>Mentha piperata</i> L.	Lamiaceae	60.3	50.3
<i>M.spicata</i> L.	-	63.3	48.2
<i>Ocimum adscendens</i> Willd	Lamiaceae	50.0	52.4
<i>O.basilicum</i> L.	-	45.1	50.1
<i>O.canum</i> Sims	-	55.1	75.0
<i>O.sanctum</i> L.	-	47.1	52.3
<i>Putranjiva roxburghii</i> Wall	Euphorbiaceae	100	100

Figure.1.Stem with Leaves



Figure.2 Pods of Sissoo



Figure.3 Wilting in 40-45 Year Old Tree of Shisham



Figure.4 Wilting of Shisham Trees in a Row Plantation along with Healthy Tree



source:Harsh,N.S.K.FRI Dehradun-248006

The inhibitory effect was found to increase as chitosan concentration increases. The 50% effective concentration value was estimated by probit analysis, and it was 1.4 mg/mL. Chitosan was more effective in potato dextrose broth where it completely inhibited the mycelial growth of FocR4 at all concentrations tested. Chitosan inhibited the sporulation of FocR4 by a maximum of 96.53% at 8 mg/mL chitosan, and 100% inhibition of spore germination was recorded at all concentrations tested. Chitosan at concentrations of more than 1.6 mg/mL was also found to induce morphological changes in FocR4 characterized by agglomeration of hyphae,

abnormal shapes, vesicles, or empty cells devoid of cytoplasm in the mycelia.

Sibounnavong *et al*(2012) found that antagonistic fungi *Chaetomium brasiliense* CB01 and *Chaetomium cupreum* CC03 antagonized *F.oxysporum* f.sp. lycopersici NKSC02 race 2 that caused tomato wilt of sida abd cherry varieties.The bioactivities test demonstrated the antagonistic activity of *Ch. Brasilense* CB01 and *Ch. Cupreum* CC03 inhibited production of *F. oxysporum* f. sp. Lycopersici race 2 conidia.Tongbram *et al*(2012)investigated the antifungal effect of aqueous extracts of locally available plant species in vitro conditions against *F.*

udum, the causal agent of Fusarium wilt of pigeonpea. Among the plants tested higher inhibition was noticed in *Allium sativum*, *Azadirachta indica*, *Spilanthus acmella* and *Adhatoda vasica*. In field experiment, aqueous extract of *A. sativum* showed maximum disease control. Rosado-Álvarez *et al* (2014) observed a significant inhibition of mycelial growth and sporulation of *F. oxysporum* f. sp. asparagi, *F. oxysporum* f. sp. dianthi and *F. oxysporum* pathogenic to strawberry upon addition of the asparagus extract. The latest research of Kamel *et al*(2015)suggested that haliscosamine is a potential candidate against *F. oxysporum* f.sp. melonis and with the possibility to use in phytopathology. Kumar(2014)also reported bioactive potential of the essential oil of *Putranjiva roxburghii* Wall with absolute fungal toxicity at 500ppm. (Table 3)following inverted petri plate technique against wilt pathogens causing wilt in shisham.The MIC of the oil was found to be 500ppm against both the test fungi.The root, bark and seed extract of *Putranjiva* showed 100% mycelial inhibition of both test fungi at 1;10 dilution.A small pilot experiment at nursery level upto two year as a mixed plantation of sissou and *Putranjiva* showed complete protection of wilting.So in order to protect sissou *Putranjiva* may be used against *Fusarium* after successful large scale mixed planation field trials.The monoculture concept for sissou need to be discouraged because shiham wilt now in epidemic stage.

In conclusion, Sissou is an important timber and effective medicinal tree various diseases. The wood and bark of Shisham have abortifacient, anthelmintic, antipyretic, aphrodisiac, expectorant and refrigerant properties and used much for treatment of wounds and gonorrhoea. Shisham wilting is due to attack of root and stem rotting organisms that live and feed by attacking either the aerial or under ground parts of the

plant. It can be prevented by combining practices like the prevention of the root injury, maintenance of capacity of a soil by nutrient management, avoiding any haphazard use of pesticides and chemical fertilizers and adopting regular cultivation practices. A complete survey of the disease in different ecological zones is necessary to make proper evaluation of the damage caused by the wilt in the natural, irrigated plantations and all along the canals and roads. Being an economical tree of Asia, all Asian countries can have research consortium, exchange of new findings and develop a common program for the managing the disease.

The dead, wilted and die- back plants should be uprooted to check sources of the pathogens to stop further spread of the disease. Plantations on clayey and waterlogged soils should be avoided. Mixed cropping is recommended to avoid wilting. New shisham nurseries should be raised from the seeds and cuttings of the resistant variety to replace the susceptible varieties. Watering is beneficial during relatively dry autumns and during dry summer months. Use Benomyl to check wilting in young Shisham plants. Add organic materials such as farmyard manure along with some antagonistic fungi to reduce the spread of the pathogen.xchange. The work(Kumar,2014)reflects that major cause of shisham wilting is species of *Fusarium*. Their management is possible through mixed plantation with *Putranjiva*.

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