Review Article

Factors Leading Towards *Dalbergia Sissoo* Decline (Syndrome) in Indian Sub-Continent: A Critical Review and Future Research Agenda

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Abstract | Sissoo (*Dalbergia sissoo*) of family Papilionaceae, is a large deciduous multipurpose timber tree. In Indian-subcontinent, the tree is cultivated in forest plantation as well as avenues, road sides and canal banks. Because of greater strength, elasticity and durability, the wood is highly valued as constructional and general utility timber. This review article shows the work conducted on sheesham decline syndrome especially die back and wilt in Indian sub-continent. A diversity of plant pathogenic fungi has been identified and isolated from the various affected sheesham trees from Indian sub-continent, yet the actual cause of the diseases is still controversial. It is pertinent to mention here that no viruses or any bacteria has been reported from a singly tree in whole of the Indian sub-continent. Although the involvement of the insect's species has been recorded and authenticated by various scientists reporting that these acts as the carrier of the fungal spores and produce tunnels in the bark of the trees. Since, many extensive filed surveys of forests, avenues, road sides and canal banks has been made to calculate the total losses and mortality of the sheesham trees in Indian sub-continent. Up-till now billions of shisham trees have been destroyed because of decline or dieback disease but unluckily there is no suitable solution against this disease. There is a need to develop the resistant varieties and to improve the quality of seed. Disease may be reduced by selecting the improved genetic material. Because it will have a good impact on product quality, economic output and its potential against insect pest or disease.

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Introduction

Dalbergia sissoo is one of the precious deciduous trees, growing up to 30 m long and 80 cm in width in a suitable condition. Its local names are *Dalbergia sissoo* (Arabic), Bengali shisu, shishu, sisu (Bengali), Bombay blackwood, sissoo, Indian rosewood, sisso in English, gette, kara, shisham, agaru, biridi, tali, sisam, sissai, sissu, sissoo in Hindi, while in Indonesian it is called as pradu-khaek, du-khaek, sonowaseso (Javanese), in Nepali it is called as sissau, sisham, named as Sanskrit aguru, shinshapa in Sanskrit, siso in Spanish, sisuitti, sisso, nukku kattai, yette, gette (Tamil), du-khaek, pradu-khaek in Thai, sissoo, shisham is a trade name. The generic name Dalbergia is based on the name of the Swedish brothers Nils and Carl Dalberg, who lived in the 18th century. Nils was a botanist and the latter delve Surinam. Its equatorial genus with round about 100 species in different regions of tropical Asia, North

America and Australia (Thothathn, 1987). Out of the twenty-seven Dalbergia species, fifteen native species are prevailing in Indo-Pak subcontinent (Mukhtar et al., 2010). Shisham (*Dalbergia sissoo*) is one of the important and substantiate forest species of this genus distributed in different tropical to subtropical regions of Africa and Asia. Along with these, it is also grown in Java, Nigeria, Mauritius, Srilanka, Kenya, Northern Zimbabwe, Palestine, and South Africa (Tewari, 1994). This deciduous tree is native to foothills of Himalayas primarily growing along the bank canals, on roadside, railway lines and along water channels of agriculture fields. Variety of soil types is favorable for its growth (Champion et al., 1965; Orwa et al., 2009). About 154,886-hectare area of Punjab is under cultivation of this tree with 28,000m^3 average annual production (Khan and Khan, 2000). The survey of eleven districts of Punjab was conducted in 2004 and results showed 20.5-40.4% seed mortality from these areas (Khan et al., 2004). The average forest area of world is one hectare per capita but Pakistan has only 0.0265 hectare that's why it is a forest deficient country. Approximately 200 million trees are present in Punjab, of which 90% are present in irrigated areas. Shisham along with other species like Phulai (*Acacia modesta*), Kikar (*Acacia nilotica*), Bakain (*Melia azadirachta*) and Ber (*Zizypus muritiana*) is one of the important timber trees in Punjab region (Qurashi, 2004). This multipurpose tree is also cultivated in tropical and subtropical areas of different continents of the world (Tewari, 1994; Afzal et al., 2006).

Importance of sheesham

The importance of sissoo tree can be describe as it is one of the fast-growing multipurpose trees. It is easily propagating, it provides us high economic return, it has a nitrogen fixing ability. It is a high demanding forest specie. This multipurpose tree is economically very important because it is use as a medicinal tree for the cure of different diseases (Qurashi, 2004). About 80% of Pakistani people living in a rural area still use the herbal medicines (Anonymous, 1997). Different part of this tree like roots, barks, leaves, wood, and seeds are used for the treatment of different diseases like expectorant, aphrodisiac, eye and nose disorders, nausea, dysentery, stomach problems, syphilis, blood diseases, and skin diseases (Duke and Wain, 1981). Other troubles like ulcers, leucoderma, emesis, dysentery can be cure by the remedy of this tree (Nadkarn, 1954; Chopra et al., 1956; Kirtikar and Basu, 1993). *Dalbergia sissoo* containing the medicinal properties overcome the bacterial virulence as it is antidiarrhoeal while its antimicrobial activity is zero (Brijesh et al., 2006). For excoriations, gonorrhea, and skin ailments *Dalbergia sissoo* is a folk medicine (Duke and Wain, 1981). Leaf extract of *Dalbergia sissoo* has febrifuge and moderate anesthetic properties due to alcoholic compound (Hajare et al., 2000). Ayurveda is also recommended the leaf juice for eye ailments. Leaf extract of *D. sissoo* has no side effects on gastric mucosa and have a remarkable anti-inflammatory effect (Hajare et al., 2001). D. sissoo leaf is also used to treat nonspecific diarrhea in animals specially in India and Nepal. Leaf extract was used to treat gonorrhea, syphilis, dysentery, heart problems and sore throats since the old time (Al-Quran, 2008). *Dalbergia sissoo* is an effective antiseptic used for the prevention of chronic bacterial infections along with Datura stramoium with cow urine (Yadav et al., 2008). D. sissoo is also reported to cure burning sensation of the body, scalding urine, scabies, syphilis and digestive disorders (Kirtikar and Basu, 1933; Sharma et al., 2001; Ishtiaq et al., 2006; Ahmad, 2005). Sultan et al reported that for long hair and to remove dandruff boiled leaf extract of sissoo is used (Sultana et al., 2006). Its oil has stronge repellent action (Ansari et al., 2000). Bark and wood are considered to expectorant, aphrodisiac, aperitif, antipyretic, anthelmintic, abortifacient and refrigerant. Its bark contains antioxidants which can cure inflammatory problems (Kumari and Kakkar, 2008). Its wood also has some indigenous medicinal properties for leprosy, nausea, eruptions and boils (Kirtikar and Basu, 1975). The bark and wood are hot, acrid, bitter, aphrodisiac, expectorant, antipyretic allays thirst, vomiting, cures skin diseases, ulcer, leucoderma, dysentery, abortifacient, diseases of the blood and dyspepsia (Ahmad, 2007). It is a stimulant used remedies and folk medicine (Nadkarni, 1954). Sheesham is a cash tree because it financially supports the farmer by selling wood which is used in making furniture, plywood industries, construction work and fuel purposes. It is a cheap source of making indigenous medicines for the cure of different diseases (Azaizeh et al., 2003).

Diseases on Sheesham tree

Major disease on sheesham is dieback, decline and wilt. Decline is usually defined as the decrease in growth and strength of the plant. However gradual and complete destruction of the crown part of tree is called dieback. After 3 to 5 years of symptoms appearance tree may start to die. Several diseases

cause damage to sheesham tree i.e die back, leaf blight, collar rot, leaf blight, leaf rust, powdery mildew, wilt, Ganoderma root rot Khan et al. (1965), Khan and Bokhari (1970), Bakshi (1954) and Zakaullah (1999). Symptoms appeared in a crown region and then move progressively downward in dieback of shisham, the common symptoms of dieback are thinning and drying of branches and leaves, drying up of crown region that leads the stag headedness in severe condition (Khan, 2000; Bajwa et al., 2003b). Chlorosis, progressive defoliation, leaf thinning and finally death of the tree is reported in wilting of shisham (Bakshi, 1963; 1976). Wilting starts from the bottom and move towards the top and cause the death of tree in a moth irrespective of its age (Bajwa et al., 2003a). The Tarai track of Nepal is considered the origin of *D. sissoo* decline. Shisham is grown in Pakistan about hundred years ago from Nepal (Khan et al., 2004). The characteristics symptoms of *D. sissoo* is wilting (in severe cases caused the death of tree), leaf and branch desiccation, color changes (Baksha and Basak, 2000; Tantau et al., 2005). Canker, Necrosis, internal chlorosis and wilting are the otsher prominent symptoms reported in diseased plant (Fatehetal, 2006). It is reported that the symptoms of sisso dieback show similarity with mango dieback in southern region of Pakistan Khan et al., 2004). Different pathogens are involved in shisham decline like *Polyporus* sp., *Ganoderma* sp., and *Fusarium* sp., caused the root decay of shisham tree in track of tarai Nepal, *Fusarium solani* caused the wilt in shisham (Mukerjee et al., 1971). *Fomes lucidum* caused the quick death of the tree by attacking on the roots of healthy shisham tree Parker (1918). *Fomes lucidum* is considered the most damaging fungi for maximium mortality rate in of shisham Troup (1921) whereas *Phellinus gilvus* is associated with butt and root rot diseases Bakshi (1974). Pathogen is usually considered the facultative parasite, it attacks the tree on its advanced age and stop the stag- headed condition. The pathogen caused a white rot in heart wood and sap wood. The pathogen produces sporophores which are usually leathery in fresh condition, imbricate or single, annual, sessile, reflexed, effuse-reflexed, hairy sub-zonate in forma gilvoides or smooth with concentric zonations in forma licnoides; in brown, yellow and red colour, sterile, thick, margin developed on stem and roots surfaces (Bakshi, 1974; 1976). The root galls on diseased shisham is abserved to cause by pathogen *Meloidogyne javanica* Lachhiwala range nursery, Dehra Dun (Mehrotra and Sharma, 1992). No bacterial and viral diseases is reported to cause any disease on *D. sissoo* but polyphagus nematode is reported to caused diseases on its other species (Sharma and Mehrotra, 1992).

Cause of decline

It is reported that biotic and abiotic factors both are involved to cause the sissoo decline as it is a tangled disease (Sharma et al., 2000; Basak et al., 2000). Various biotic and abiotic factors are heat, insects, pathogen, drought as they stop the normal physiological working of the tree (Bukhari et al., 2015; Naz et al., 2015). One of the reasons of the high mortality of the disease is monoculture. The diseased and the healthy plant root system are in contact in monoculture plantation and pass the infection from diseased plant to healthy one. It is one of the reasons of rapid spread of wilting regardless of tree age in Bangladesh Mukhtar et al. (2010). Sharma also reported that the disease is laterally spread through roots contact (Sharma et al., 2000). Unauthentic and seed from monocultured plantation are used for further sowing in Nepal (about 90%) (TISC, 1999a; Dhakhal, 2000). Monoculture is considered as the spread of disease in Nepal (Parajuli et al., 1999; Foresc, 1997). The reason behind the low production of *D. sissoo* is decline, dieback and high mortality rate of seed and seedlings (Khan and Khan, 2000). During storage the fungus pierce into the seed coat or embryo and effect the germination of seeds and seed mortality (Bhansli and Jindal, 1997). It is proved at Pakistan Forest Institute that Ganoderma lucidum which is a root rot fungus is a primary disease-causing agent and borers that attack the stress tree is considered as a secondary invader (Khan, 2000). In 1998, the professors of different disciplines working on various insect species verified that Coleoptera: Scolytidae (pinhole bark beetle) as a primary pathogen and saprophytic fungi in galleries along with Coleoptera: Cerambycidae (long horn beetle) worked as a secondary pathogen. *Ganoderma lucidium and Fusarium* sp. in association with stem borer insects are supposed to be the cause of shisham dieback (Parajuli et al., 1999). An unidefined root nematode was also supposed to be the cause of shisham dieback (Foresc, 1997). Due to the attack of stem borer the cortical layer of every decay shisham tree has destroyed in Nepal. It is to be noted that every dying tree are from such area having compact and water-logged soil. It means that the soil condition also plays major role in sisso decline (Khan and Khan, 2000). Overexploited forest planning

and mismanagement is also considered as one of the reasons of shisham decline Mukhtar et al. (2010). An association between *Fusarium solani* and *Delbergia sissoo* was found in various part of world (Bakhshi, 1954; Manadhar and Shrestha, 2000; Bajwa et al., 2004; Rajput et al., 2010; 2011). It was recorded that *Fusarium solani* and *Rhizoctonia solani* were cause of high mortality in shisham, it also reduced germination Mustafa et al. (2004). *Aspergillus*, *Fusarium* and *Alternaria* were also some association with shisham decline Manadhar et al. (2000) (Table 1, 2).

Abiotic factors

Diseases usually occur due to the change and severe climatic condition that badly effects the physiological function of shisham trees (Singh, 1980; Kaushal et al., 2002). Wilting symptoms were observed throughout the shisham plantation in UP, India Bakhshi (1954). The change in climatic condition, unavailability of nutrients and the fungal pathogen are considered the primary factors in causing the decline symptoms (Simpson, 1993). In a favorable condition, the crown of tree start drying and eventually become die (Pathan et al., 2007). Due to continuous present of water in the root zone, the water table rise and O_2 level start decreasing allows the fungal pathogen to cause root infection. When the water table ascent up to only 2-3 m depth of soil, the tap root meets water table and become more susceptible to *Fusarium* sp. The experience that sissoo thrives on loosely textured soils but suffers adversely from root diseases in stiff clayey soils has been widely accepted. The success of the species on loosely-textured soils appears to be proper soil aeration and good drainage which leads to the healthy growth of roots (Bakshi, 1954, 1957; Bagchee, 1945). According to Sah et al. (2003) soil texture is one of important factor to cause decline irrespective of its primary factor because it disturbs the nutrient cycle of plant. Plantation on poorly drained soil are more susceptible than on sandy, well drained soils. Pathogens are considered the secondary cause of disease; the primary cause is still controversial (Manion, 1981). Unknown toxin found from the cultural filtrate is also involved in causing wilt symptoms (Bakshi and Singh, 1959). Soil texture and its relationship with pH and incidence of wilt disease with these factors was studied by Bakshi et al. (1957). Disease was not found in good drainage condition and soil with more sand and low silt however the disease was observed in soil containing more silt and less sand. The pH of soil in diseased plantation was observed 7.5 – 9.7 as compared to normal in northern districts of Bihar like Muzaffarpur, Gopalganj, Siwan. The high mortality rate of shisham decline was recorded in Uttar Pradesh, Haryana and Bihar. The following factors may have played a role in making sissoo more vulnerable to the pathogens *Fusarium* and others.

Water Stress: It is recorded that in Haryana (Karnal Forest Division) 110ha of shisham plantation were grow in 1952 to 1960, watered the plant up-to 1963. They used shallow channels system for irrigation followed by superficial root system. After 1963, irrigation was stopped in 9 coupes out of 11. After three years disease mortality was in all 9 coups. While in the other two coups no disease mortality was observed due to the availability of water. the area where water is insufficient, plant's roots are not able to draw water from deep water table, so water stress is also a reason behind the high disease mortality of shisham decline Bakshi et al. (1972).

Soil Texture: The high mortality of shisham decline was reported in Saharanpur and Dehradun district of Taungya forest where all tree became pale yellow and suddenly died (Bagchee and Singh, 1954). Such symptoms were also seen in in Lachiwala Range of Dehradun Forest Division. Bakshi et al. (1957) reported that high mortality is due to the bad soil texture. It might have some effects on growth of shisham tree as disease was not observed in light textured soils but in clayey soil.

High Water Table: About 100% mortality was observed in plantation of sisso in Bhabar Forest Division and Ganganagar. The water level in these areas was remained 2-3 m always. According to an Indian survey when the roots of plant touches the water table zone, the chances of disease has increased specially the attack of *Fusarium solani* which cause infection and finally the death of tree. The tree with 10-12 years age shows mortality at 2-3m deep water table while with 2 m water table, mortality expressed at the age of 5-6 years age and with lesser water table mortality started at 12-14 years age (Bakshi et al., 1972; Singh, 1980). It is observed that shisham tree growing at stressful location allow 60% carbon for roots and 40% for foliage while root at normal site consumed 51% and foliage 49% of carbon (Negi et al., 1999).

Table 1: *Fungi isolated form different parts of sissoo in Pakistan.*

Fungi Isolated	Nature of disease	Plant part affected	Reference
Ganoderma lucidum	Soil borne	Roots	Khan and Gull, 1988
Polyborus gilus	Soil borne	Roots	Khan and Gull, 1988
Fusarium oxysporum	Soil-borne	Roots,	Khan and Gull, 1988
Poria ambigua	Soil-borne	Roots,	Khan and Gull, 1988
Rhizoctonia ap.	Soil-borne	Roots	Khan and Gull, 1988
Botryodiplodia sp.	Soil-Borne	Roots,	Khan and Gull, 1988
Fusarium sp.	Soil-Borne	Roots, Wood,	Manadhar and Shrestha, 2000
Phoma sp.	Leaf blight	Leaves	Manadhar and Shrestha, 2000

Table 2: *Fungi isolated from different parts of sissoo in Nepal.*

Fungi Isolated	Nature of disease	Plant part affected	Reference
Slternaria sp.	Seed-borne	Seeds, Pods	Manadhar and Shrestha, 2000
Aspergillus spp.	Seed-borne	Seeds, Pods	Manadhar and Shrestha, 2000
Botryodiplodia sp.	Soil-borne	Roots,	Manadhar and Shrestha, 2000
Cladosporium sp.	Soil-borne	Seeds, Pods,	Manadhar and Shrestha, 2000
Colletotrichum sissoo	Air borne	Leaves	Manadhar and Shrestha, 2000
Fusarium solani	Soil-Borne	Roots, Wood,	Manadhar and Shrestha, 2000
Fusarium sp.	Soil-Borne	Roots, Wood,	Manadhar and Shrestha, 2000
Ganoderma sp.	Wood rot	Wood	Manadhar and Shrestha, 2000
Maravalia achora	Leaf blight	Leaves	Manadhar and Shrestha, 2000
Phoma sp.	Leaf blight	Leaves	Manadhar and Shrestha, 2000
Phyllachora dalbergiae	Leaf spot	Leaves	Manadhar and Shrestha, 2000
Phyllactinia dalbergiae	Powdery mildew	Leaves	Manadhar and Shrestha, 2000
Polyporus sp.	Wood rot	Wood	Manadhar and Shrestha, 2000
Uredo sissoo	Rust	Leaves	Manadhar and Shrestha, 2000

Biotic factors

Many pathogens are reported to cause the sissoo decline that's why there is a confusion about the causal agent of D. sissoo decline (Bakshi, 1974). The root inhibiting fungi *Ganoderma lucidum* is supposed to be the primary agent of sissoo dieback as the pathogen infects the root. The root contact is considered its lateral spread. (Sharma et al., 2000). *Phytophthora cinamomi* is also considered the primary cause of sissoo dieback (Gill et al., 2001). Manandhar and Shrestha reported *Fusarium solani* as the causal agent of this disease (Bakhshi, 1954; Manandhar and Shrestha, 2000; Bajwa et al., 2003). The fungus has been reported to be present in roots, its hyphae or jelly like substance restricted in vessels and cause wilting (Bakhsai and Singh, 1959). According to Parajuli et al. (1999) *Fusarium oxysporum* along with *Ganoderma lucidum* and *Fusarium solani* are also involved in shisham dieback but their pathogenicity tests have not been confirmed (Anonymous, 2000). Different species of fungi and insects involved in causing *D. sissoo* decline has been reported from tropical and sub-tropical region (Beeson and Bhatia, 1937; Beeson, 1941; Browne, 1968; Bakshi, 1976; Joshi and Kumar, 1986; Sharma and Bhardwaj, 1988; Sheikh, 1989; Sharma et al., 2000, 2011). Fungal dieback in association with canker and wilt has also been observed in subcontinent (Bagchee, 1953; Bakshi, 1963, 1976; Browne, 1968; Khan and Khan, 2000; Bajwa et al., 2003a). In Pakistan and north India, *F. solani* has been recorded to cause systemic wilt in shisham (Bagchee, 1961; Bakshi, 1974). In India, *G. lucidum* and *Neocosmospora vasinfecta* var. *africana* damaged the plantations and natural forest of shisham (Bakshi, 1974).

Entomological studies

Several insects' species, approximately 125 acts as a damaging defoliator in the adult age of shisham tree specially *Lepidoptra: Noctuidae (Plecoptra reflexa)*

and *Lepidoptra: Gelechiidae* (*Dichomeris eridantis*). In 1899, a serious damage of defoliators was observed in Change Manga Pakistan and then in Khanewal and Chichawatni in the adult stage of plant. The larvae of pinhole (Buprestidae) and beetles (Curculinidae) were recorded to caused serious damage on sissoo plantation (Foresc, 1997). A pinhole beetle Coleoptera: Scolytidae (*Xyleborus* spp) in its larvae stage gain nutrition from the Ambrosia fungus in both from the heartwood and softwood. It is reported as the cause of disease in plains of Punjab (Tiwari, 1994). In the northern region of sub-continent India, *Perissus dalbergiae* and *Agrillus dalbergiae* has been recorded as the causal agent as they gild the stem in favorable condition (Tiwari, 1994). The cracks and galleries may be flocked with hyphae attacking wood of dying trees in association with some other causes. *Poria ambigua* another root and butt rot fungus are widely identified associated with Sinoxylon beetles. The tunnels are with the fungus growth. Rhizoctonia, a soil fungus, has also been reported as causal agent to the root system of sissoo at higher soil moisture levels (Khan, 1989). A similar study conducted by a panel of multidisciplinary experts have indicated pinhole bark beetle (Coleoptera: Scolytidae) as a primary disease-causing agent, and the long horn beetle (Coleoptera: Cerambycidae) as a secondary invader in association with saprophytic fungi in the galleries. Xyleborus spp (Coleoptera: Scolytidae), a pinhole beetle, both of sapwood and heartwood with larvae feeding on Ambrosia fungus, has been identified as a causal agent in the plains of Punjab (Tiwari, 1994). Batocera and Dorysthenes spp (Coleptera: Cerambycidae) have also been reported as root and bark feeding insects particularly on unhealthy and decaying bark throughout' the plains of India and Pakistan. Eggs are laid under bark and on wounds of stem, shoot and twig. Emergence is most common in May, June, and July. Batocera rubus beetle usually emerges in March-April. Life cycle for Batocera spp varies from 1 to 2 years while that of Dorysthenes spp is 3 to 4 years or even more. The leaves of the attacked trees turn yellow and the tree dies slowly after 2 to 3 years. *Agrillus dalbergiae* and Perissus dalbergiae have been reported as causing girdling of the stem particularly in the northern part of the Indian sub-continent (Tiwari, 1994). Since the pathogenic insects complete a phase of their life cycle on the host tree, the damage caused is usually reversible on reduction of their numbers. However, damage caused by fungi is insidious and usually irreversible (Khan, 1989).

Major constrains

Over the last few decades, this deciduous tree is fighting for its survival._In subcontinent, the forest economy was in loss as they faced the loss of million dollar due to the high mortality of shisham decline (Dayaram et al., 2003). In subcontinent, the three major cause of sissoo deforestation are improper planning and mismanagement of sissoo distribution, use of susceptible varieties of this plant and smuggling and illegal cutting (Mukhtar et al., 2010). Millions of sissoo trees due to its high wood quality have been felled or illegally cut and smuggled by timber mafia and habitual forest offender. In Tarai region of Uttar Pradesh, high mortality rate of shisham decline was recorded by Bakshi (1957). Up-till 1900 shisham decline is not considered an alarming situation but after that in 1998, it is recorded as an epidemic disease in central Punjab Province (Naz, 2002; Bajwa et al., 2003). Shisham decline was assumed as a destructive disease in Sindh, Pakistan (Rajput et al., 2010). The disease incidence recorded in Sindh Province along the roads and highways are 40-50% and 60-80% respectively (Rajput et al., 2010). The maximum disease mortality of 55% was observed in Bangladesh (Webb and Hossain, 2005). In another survey, it was recorded that 40% plantation along roadsides and highways and 80% around the bank canals are affected by shisham decline (Bajwa et al., 2003). Khan et al. (2004) carried out a survey from the 11 districts of Punjab Pakistan and observed 20.5-40.4% disease mortality. Another report reveals the 50% disease incidence along the canals and road side while less than 10% was recorded in Punjab, Pakistan (Rajput et al., 2010). Khan and Bokhari (1970) conducted a survey in irrigated sissoo population in Bhagat, Punjab. The study revealed that trees are dead or dying due to die back disease. Out of seventy-four trees one tree was diseased. The total ratio was 21% and total loss was approx. 31%. According to an Indian report, a survey was conducted in Haryana. A high disease mortality was recorded in Ginnaur along the canals, about 400 shisham trees were affected from wilt disease while the other trees like Jamun, Pinnata, *Albizzia lebbeck,* neem and Eucalyptus were still healthy may be because the area was silty, and water logged. In another survey in Yamuna and Bhiwani sissoo plantation was affected due to the soil stiffness. While 30% mortality was recorded in in major plantation of Hissar, Sirsa, Gurgaon and Rohtak (Table 3, 4, 5).

Table 3: *Epidemics record, trees mortality percentage and losses calculated in Pakistan.*

Province	Area	Year	Trees Mortality %	Reference
Punjab	Canal side Road side Agriculture land	2010	80% 40% <10%	(Rajput et al., 2010).
	Canal side	2013	30%	(Rajput et al., 2013)
	Canal side	2004	20.5–40.1%	Khan et al. (2004)
	Punjab	1990	5%	(Gill, 2001)
	Punjab	2000	25%	(Gill, 2001)
	Punjab	2001	43%	(Gill, 2001)
Khayber Pakhtoon Khaw	Overall mortality Healthy Half dead Severely attack Completely dead	2004	80% 16% 35% 20% 14%	(Chaudhry, 2004)
Sindh	Road sides Canal Banks	2010	60-80% 40-50%	(Rajput et al., 2010).

Table 4: *Epidemics record, trees mortality percentage and losses calculated in Bangladesh.*

Trees Age	Year	Plantation type	Affected area	Disease mortality %	Reference
2	1994	Comilla roadside plantation	60%	60%	Edward et al., 2005
3	1996	Jessore homestead private plantations	60%	40%	Edward et al., 2005
2-3	1996	Jessore homestead private plantations	50%	40%	Edward et al., 2005
5	1996	Kustia roadside plantation	50%	100-150%	Edward et al., 2005
15-20	1996	Darsona college campus	50%	75%	Edward et al., 2005
2-20	1997	Islamic University campus, Kustia	50%	100%	Edward et al., 2005
5-8	1999	Fisheries Research Institute campus, Mymensingh	50%	8%	Edward et al., 2005

Table 5: *Epidemics record, trees mortality percentage and losses calculated in Bangladesh.*

Area	Year	Trees mortality %	Reference
Haryana, Assam, Bihar, Utter Pradesh	2002	10-20	(Solanki, 2002)
Haryana	1997	0.7 Million trees	(Solanki, 2002)
North Gonda (UP)	2002	12	(Negi, 2002)
Monera	2002	1-5	(Kumar and Rai, 2002)
Piplee block of Bareilly forest division UP	1980	20-30	Bakshi et al. (1972) (Singh, 1980)
Pathri and Mohand	1992	23-40	(Sukhla, 1992)
Kaleshwar range of Haryana	1994	15	(Mehrotra and Pandey, 1994b)

Future national/ international strategies

Sissoo mortality is now become a major problem of many countries like Pakistan, India, Bangladesh, Nepal. It is needed to urgently do some collaborative studies. It should be noted that in Bangladesh Sissoo seems to have a very narrow genetic base.

Identification of shisham varieties

The researchers of Punjab university Lahore identified 18 different varieties of shisham in which two are resistant, four are named as susceptible and 12 are named as unspecified as these varieties did not show any disease symptoms but their resistant potential was not measured because their number was not large enough. Based on physical appearance Javaid et al. (2003) identified nine phenotypically different shisham varieties on the bases of physical appearance of the plant, branching pattern, leaf and leaflet size and shape, pod characters, branching and leaf density and stem surface characteristics. Later, Javaid et al. (2004) identified nine more varieties on the bases of these characters. They also reported that

these phenotypically different varieties varied in their response to wilt and dieback diseases in the shisham plantations. ISSR markers detect polymorphisms in microsatellite and inter-microsatellite loci (Zietkiewicz et al., 1994), and have been widely used to evaluate genetic diversity and population structure (Esselman et al., 1999). ISSRs have been used to estimate the extent of genetic diversity in a wide range of plant species including *Eleusine coracana*, *Vigna* spp., *Ipomoea batatas* and *Plantago* (Mukherjee et al., 2013).

Local adaptability of sissoo

Neil (1989) and Joshi and Thapa (1997) have observed the growth and development of few local shisham plantation. Comparison of different sisso plantation of Nepal and Pakistan provenances was studied by different researcher and it was noted that Nepal province were better than Pakistani provinces. There is a need to test the local adaptation of shisham plantation in these provinces. Systematic testing was recommended in Nepal provinces (Neil, 1989; Bara et al., 1997).

Management

Up-till now billions of shisham trees have been destroyed because of decline or dieback disease but unluckily there is no suitable solution against this disease. Different seminar should be conducted to aware the people about the disease and its management (Javaid, 2008). It was studied that soil was not only single factor responsible for shisham decline, many pathogenic fungi were also involved in it (Sah et al., 2001). Exotic seeds from India are openly exported to Nepal. Such exotic seeds from unknown source should not be used or planted before testing (TISC, 1999a). All crucial information about the plant and disease like history of disease, rate of epidemic, about its pathogens, its resistant varieties, expected environmental conditions, locality, availability of labour, cost and land must be collected before doing any management (Agrios, 2005). There is a need to develop the resistant varieties and to improve the quality of seed. Disease may be reduced by selecting the improved genetic material. Because it will have a good impact on product quality, economic output and its potential against insect pest or disease (Hansen and Kjaer, 1999).

Biological control

Effectiveness of different fungicides like Antracol, Copper oxychloride, Dithane M-45, Ridomil Gold, Topsin-M, Alliete were checked against the Fusarium solani by using poisoned food technique (Nene and Thapliyal, 1979). Later, different concentration of these fungicides was tested to inhibit the fungal growth, fungicide like Ridomil Gold and Dithane M-45 are highly effective against *F. solani* whereas Topsin-M and Alliete are intermediate sensitivity while Copper oxychloride and Antracol are least effective in reduction of fungal growth. Ridomil and Benomyl showed highest sensitive record to inhibit the mycelia growth of *Fusarium solani In-vitro*, whereas Alliete exhibited least effect against this fungus, while Benomyl was only effective under *In-vivo* (Bajwa and Javaid, 2007). It is also reported that Dithane M-45, Captan, Ridomil and Bayleton were highly toxic and inhibited *Fusarium solani* under *In-vitro* (Mamatha and Ravishankar, 2005). The mycelial growth of *B. theobromae* was destroyed by carbendazim at 400 ppm (Banik et al., 1998). It is also reported that Benlate at 100 ppm is highly fungitoxic to *Colletotrichum gloeosporioides*, while Benlate at 100 ppm along with Topsin-M at 50 ppm completely inhibited the linear colony growth of *B. theobromae* isolated from shisham (Mahmood et al., 2002). The other most effective fungicide that control the growth of *Lasiodiplodia theobromae* are Thiophanatemethyl and Carbendazim (Khanzada et al., 2005). In vitro study of fungicides (benomyl, 0.1%) and thiophanate-methyl (0.1%) showed their effectiveness against *B. theobromae* (Shelar et al., 1997). Dennis and Webster (1971) found that mycelia growth of *F.solani* can be suppressed by Carbendazim (Bavistin) and Captan.

Chemical control

Ahmad et al. (1996) reported that Bavistin, Dithane M-45, Vitavax and Benlate could inhibit the mycelia growth of *Fusarium solani*. The other fungicide that work effectively under in-vitro and in-vivo conditions was Benomyl. The toxicant Methyl-2benzi midazol carbamate (MBC) derived from benomyl fungicide have significant effect against shisham wilting. This fungicide can be easily injected into the trees due to its stability (Mcwain and Gregory, 1973).

Bio-control of Fusarium solani

It is reported that Trichoderma spp. are antagonist as they have ability to produce both antibiotics and extracellular lytic enzymes Dennis and Webster (1971) and Elad et al. (1982). Chitinolytic enzymes are released by *Trichoderma harzianum* which are effective to suppress the growth of different pathogenic fungi (Lorito et al. 1993). Similarly, these enzymes produce

volatiles which inhibit growth of Phytophthora spp. and caused vacuolation of its cell contents followed by break down of fungal hyphal tips Brasier (1975).

Conclusions and Recommendations

Various suggestions are recommended below to tackle such a syndrome:

Plantations should be grown on light textured soil with well drainage conditions. Do not grow shisham plants in clayey and waterlogged soils. In nurseries, before sowing seeds of shisham should be disinfected. To reduce the further disease spread, wilted, dead or dying plants or stumps should be immediately remove from the field otherwise they will act as a potential source of infection. Field should be completely free from decaying wooden pots, wooden fragments and fungal fruiting bodies as they spread disease. Wounding of roots and trunks should be avoided or sealed or dressed in rubber latex and grafting wax. Use resistant varieties rather than susceptible. To cure wilting use Benomyl in young shisham plantation. Avoid monoculture of plant. Used cuttings and seeds of resistant variety to grow a nursery. Mixed cropping is recommended to avoid dieback. Grow resistant plants such as *Mours* spp., or And *Acacia nilotica* along with it. In case of dieback when no specific cause is identified, do fertilization and watering. Used organic matters like farm yard manure with some antagonistic fungi to stop the pathogen spread. Over-aged affected trees should be removed from the field to overcome the rate of infection. Select a suitable site with well drained sandy soil, pathogen *F. solani* is not removed by crop rotation or by using any chemical so proper site selection is necessary for healthy plantations. Deep planting or deep irrigation is recommended so that the plant may develop deep root system. Planting hole should be deep, so the root may go to sub soil level within 2-3 years. It was revealed that plants that grown along the water channel are infected more as compared to grown in a field separately. It was also noticed that injured roots are the entry point of pathogenic fungi. If we do proper management, we can reduce the rate of wilt and dieback diseases in sheesham.

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Author's contribution

Syed Atif Hasan Naqvi and Muhammad Tariq Malik conceived the idea, Sidra Mushtaq, Ummad-ud-Din Umar, Ateeq-ur-Rehman, Shoaib Fareed and Muhammad Asif Zulfiqar performed overall management of the article.

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