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Review Article

Shisham (*Dalbergia sissoo*) decline by dieback disease, root pathogens and their management: a review

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ABSTRACT

Shisham or sissoo (*Dalbergia sissoo*) is an important multipurpose tree with great economic importance, but this tree has been infected by various root pathogens. This review article shows the works conducted on root pathogens and die back disease of Shisham and their management. Around seventy-one endophytic fungus has been found in sissoo trees in Nepal. Several fungi, including, *Fusarium solani*, *F. oxysporum*, *Ganoderma lucidum*, *Phellinus gilvus*, *Polypours gilvus*, *Rhizoctonia solani*, *Polyporus spongiosum*, etc. cause sissoo diseases. *Ganoderma Lucidum* and *F. Solani* are two main pathogenic agents in Shisham, all of which causes root rot and vascular wilt diseases, and are the causes for the large-scale death of this tree species. Root rot ganoderma is wide spread in both natural and plant-based forests. Older trees in Shisham are usually attacked by these pathogens and cause large-scale death. However, when sissoo is grown as a re-forested pure plant without the removal of the stumps or root of the initial plant, a serious problem of root rot can develop. Field sanitation and proper management of field are necessary to control the fungal diseases of Shisham. Another deleterious disease of Shisham is dieback disease, where sissoo plantations have been confirmed to this disease when the infected trees begin to get dry from the top. There is no suitable solution for control of dieback of Shisham. There is a need of developing resistant varieties and to improve the quality of seed. This review may be useful tool for Forest Pathologists and other persons who are working in forestry and natural conservation sectors.

Keywords: Dieback, Disease, Fungicides, Pathogen, Root pathogen, Shisham

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INTRODUCTION

Dalbergia sissoo (Indian rosewood) is the deciduous tree, generally known as sissoo, irugudujava, tahli, sheesham, and taland. Originally from Southern Iran and the Indian Subcontinent, it is also present in subtropical Africa and Asia in the tropics (Tewari, 1994). It is very possible that sissoo has been brought by agricultural cultivation elsewhere and is native only to the Himalayan sub-tract (Troup, 1921). It is widely spread in sandy and alluvial lands in river beds up to 1300m in the sub-Himalayan region (Manandhar, 1989). This multifunctional tree is also grown in tropical and subtropical areas of various continents of the world (Tewari, 1994; Afzal *et al*., 2006). Of the 27 Dalbergia varieties, 15 indigenous species dominate the subcontinent of Indo-Pak (Mukhtar *et al*., 2010). *Dalbergia Sissoo* is a large deciduous tree growing upto 8 feets in girth and l00 feets in height. It produces very heavy strong and tough wood. It is one of the most important timber trees used in carving, furniture, door and window frames, etc (Limaye, 1957; Kayastha, 1985; Streets, 1962). It is also found growing throughout the Terai plain (100m) to inner valley. The agriculture sector as well as agro-forestry has and significant impact on the economy of Nepal (Banskota *et al*., 2020; Shrestha *et al*., 2020). *Dalbergia sissoo* one of the agroforestry species is spread from 72m to 1,500m above mean sea level across the river forests from east to west of Nepal. It is a valued species and is popular in Nepal for its fastest growth and multi-purpose use (Sharma *et al*., 2000; Parajuli *et al*., 2017). It is the most valued species and is favored for planting because of high-income return and nitrogen-fixing ability in Nepal's terai, inner terai, and bhabar region. In Terai (Joshi, 1994), *D. sissoo* is a highly preferred species for afforestation and is estimated to cover about 90% of the plantation area (Gautam, 1996). It is extensively cultivated in Nepal, India, Malaysia, Pakistan, Myanmar, Bhutan, Bangladesh, and Afghanistan, as well as in tropical and sub-tropical Africa (Chourasia, 2012).

In various environmental conditions, the records reveal the vulnerability of sissoo to many pathogens, causing considerable harm to both plantations as well as naturally growing trees.
For the last 30 years or so this species has been the most widely planted tree in Nepal. Now, it has been started dying since last few years. Trees of varying ages right from saplings to mature trees are affected by different diseases (FORESC, 2000). The characteristic symptoms are yellowing and death of leaves in acropetal succession to the trees.The whole tree appears yellow, leaves shed rendering the branches bare. The tree shows sign of wilting and dying within few months. Sissoo mortality is one of the major national problems affecting afforestation in the country (Bashyal *et al*., 2002). Root as well as foliage damage, caused by phanerogamic parasites and poor soil drainage, are the prevalent disease having physiological disorders (Yousuf, 2002). Several diseases like blight, collar rot, leaf blight, leaf rust, powdery mildew, wilt, ganoderma root rot causes shisham decline (Khan *et al*., 1965; Bakshi, 1954; Zakaullah, 1999; Khan & Bokhari, 1970). The pathogen threatens to total production output, food shortage, food security resulting in economic and social losses (Tiwari *et al*., 2021). The root decay of the shisham tree in terai region of Nepal is caused by various pathogens, such as *Polyporus sp*., *Ganoderma sp*., and *Fusarium sp.* causes a decline in shisham (Mukerjee *et al*., 1971). *Ganoderma lucidum* and *Fusarium solani* are two main pathogens that cause root rot and vascular wilt diseases respectively. *Fusarium solani f. sp. dalbergiae* has been recorded by (Baghchee, 1945; Bakshi, 1954; Bakshi & Singh, 1959) as high loss in *D. sissoo*. It affects the vascular system, which induces moisture tension and destroys plants. Yellowing and death of leaves in accropetal series in the tree are its major

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symptoms. Because of this pathogen leaves the branches shed, pink to the reddish stain on the outer sapwood, and fungal hyphae with jelly-like substances plug the vessel with symptoms causing wilt (Bhatia *et al*., 2015). Fusarium wilting, root rot caused by *G. lucidum*, is associated with *D. sissoo* mortality (Sharma *et al*., 2000). *G. lucidum* infects roots through both intact and damaged stems, kills the bark cells, and in the sapwood, it causes white fibrous rot. Sporophores of *G. lucidum* normally look stalky, corky and then woody in a later stage. In serious condition, older trees exhibit 'stag-headedness' on the branches of the crown. In the later stage the whole tree gets leafless by the death of branches and dies in a few years (Bakshi *et al*. 1972). The common host, of *D. sissoo*, is *G. lucidum* and *F. solani* (Bhatia *et al*., 2015). The most extreme disease in *D. sissoo* is dieback; thinning and drying of leaves and branches, drying up of crown region which in extreme condition leads to stag heading and death of tree (Khan, 2000; Bajwa *et al*., 2003). The article deals with the root pathogens, *Fomos lucidus, Ganoderma lucidum, and Fusarium solani* and highlights the symptoms with its possible integrated strategies and management that can be used for controlling shisham decline.

Baral (1995) traced the first report of sissoo die-back in the plantations of Nepal to 1993. However, the official reports, from the district forest offices to the Department of Forests (DoF), and the Department of Forest Research and Survey (DFRS) were received only from the year 1996/97 (Joshi & Baral, 2020). Realising the critical nature of the problem, the DFRS immediately organised a meeting with the Community and Private Forestry Division of the DoF to jointly undertake a preliminary investigation. A team of researchers, including personnel from DoF, Tree Improvement and Silvicultural Component, and DFRS were sent to the five Terai districts (Sarlahi, Dhanusha, Siraha, Sunsari, Morang) of eastern and central development regions to quickly report on the disease incidence in the sissoo plantations. This was the first preliminary investigation of sissoo die-back in Nepal (Joshi & Baral, 2020).

Root pathogens

D. sissoo is particularly vulnerable to root pathogen which causes fungal wilting, leaf blight, root rot that is targeted by the specific pathogen to specific tree species. The genetic variation in the shisham was very low, which may be the reason for more pathogen pressure (Bakhshi, 1954; Khan, 2000; Khan & Khan, 2000; Zakaullah, 1999; Bhandari *et al*., 2014). Two shisham mortality pathogens- *Fusarium solani f. sp. dalbergiae* causing vascular wilt and *Ganoderma lucidum* were found to be responsible for root rot (Kumar & Khurana, 2016). These fungi are linked with the mortality of sissoo (Sheikh, 1989; Bakshi, 1954).

Fomos lucidus

Fomos lucidus is the most harmful fungus that contributes to high sissoo mortality (Troup, 1921). Khan and Bokhari (1970) reported that *F. lucidum*, a root and heart rot fungus, causes significant damage once it has been established, and is the most common sissoo pathogens. *F. lucidum* targets the roots of live sissoo trees and causes their death speedily, which was studied by Parker (1918).

Ganoderma lucidum

The root rot of Ganoderma in sissoo is caused by the fungus *Ganoderma lucidium* (Basidiomycota division). Ganoderma is a wide-ranging genus that encompasses woodland habitats and cultural practices (Moncalvo & Ryvarden, 1997). Many species of Ganoderma

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are important pathogens of woody plants that cause root and rot diseases (Old *et al*. 2000; Flood *et al*., 2001). *G. lucidum* has been identified as the principal causal organism in the root rot disease of several economically important arid and semi-arid tree species, including, D. *sisso*, *Albizia labbek*, *Prosopis cineraria*, *A. nilotica*, and *Azadirachta indica*, and *Acacia tortalis* group of wood-decaying macro-fungi (Bhansali *et al*., 2012; Harsh *et al*., 1993; Khara, 1993; Lodha & Harsh, 2010). In the natural forests and plantations, *G. lucidum* targets mature trees (Bakshi, 1974). This pathogen resides at the root and infects the root through intact surfaces and injured surfaces. Lateral dissemination of the disease occurs through root contact during plantations (Sharma *et al*., 2000). The usual signs of *G. lucidum* root rot of trees are leaves yellowing, decaying roots, and the emergence of a reddish-colored fungal body at the base of the trunk of the tree (Khara & Singh, 1997). Out of eight percent of diseased sissoo trees, *Ganoderma lucidum* (7.85%) and *Poria ambigua* (0.45%) were popular pathogens identified (Khan & Bokhari, 1970).

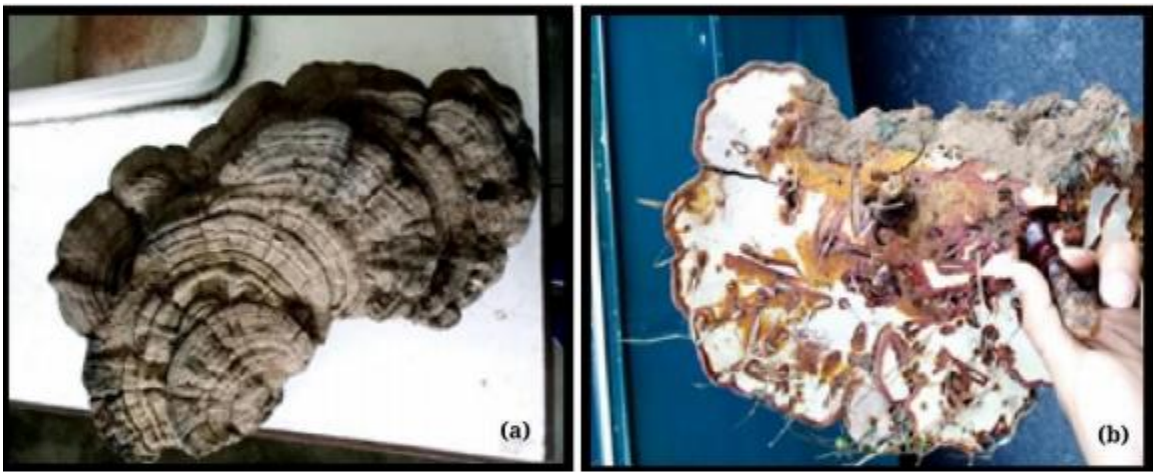

Fig.1. *Ganoderma lucidum* fruiting body. (a) Dorsal view (b) Ventral view (Timilsina *et al*., 2020)

Lifecycle of *Ganoderma lucidum*

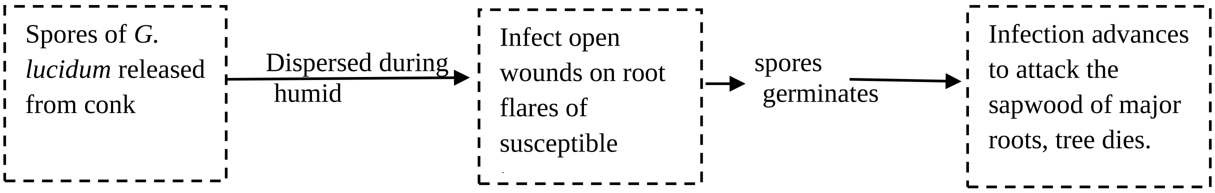

Fig.2. Lifecycle of *G. lucidum* in *D. sissoo* (Devkota, 2000)

Management of Ganoderma root rot

Residual roots and stumps removal can be one of the most substantial methods for the management of ganoderma root rot. Residual roots and stumps act as the source of infection following a clear-felling mix of certain resistance species and the digging of partisan trenches may reduce the incidence of disease (Bakshi, 1974). It was demonstrated by Khan and Bokhari (1970) that 30% of the plantation was found to have suffered from this disease. The control measures suggested were,

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- Direct seeding can enhance plantings.
- Roots and stumps infested should be eliminated.
- Root injuries can be minimized by hoeing and plowing.

Disease prevention was tested by the treatment of fungicidal seeds and soil alteration with crop residues. The prevention of disease is found with highest percentage of bavistin and

Fig.3. Fruiting bodies of *G. lucidum* causing root rot in *D. sissoo* (Bhatia, 2015).

captafol with fewer propagules per unit of soil. Minimum seedling mortality was reported in soils modified by bean straw and sawdust (Kaushik & Singh, 1996). They also proved that Bavistin (carbendazim) and Captaf (captain) was effective against ganoderma root rot. Further in a study conducted, it has been found that polyporus 23 sanguineus, inhibited *G. lucidum* formation, which indicates that this species can be used for biological control (Shukla & Rana, 1996). Bioagents as *T.harzainum*, *Trichoderma viz. T. viride* and *T. pseudokoningii* can be used to prevent root rot disease caused by *G. lucidum*, *T. harzianum* (68.5%) accompanied by *T. viride* (65.7%) and *T. pseudokoningii* (61.11%) control and radial growth of fungi is constantly decreased (Chet *et al*., 1981; Siddiquee *et al*., 2009; Bhaskaran *et al*., 1994). Mancozeb, Bavistin, and Propiconazole, the chemicals fungicides, were found to be the most effective in fully inhibiting fungal growth (100%) even at lowest doses (Ariffin *et al*., 2000).

Fusarium solani

Sissoo was reported to be infected on the water-logged soils by a fungus Fusarium species (Sah *et al*., 2003). There exist avirulent and virulent strains of *Fusarium solani f. sp. Dalbergiae* in *D. sisso*. The pathogen moves upward to stem through the roots. The reason for the wilt and death of the sissoo is *Fusarium solani* (Bakshi *et al*., 1956). *F. solani* was investigated from diseased roots and believed the organism as the origin of shisham decline (Shakir *et al*. 1999). (Davis *et al*., 1953) observed that wilt is usually a result of a root or lower portion of a stem attack by Fusarium, where its growth inhibits the healthy flow of

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water and excreted toxins. *Fusarium oxysporum* is also the cause of shisham wilt, according to some researchers (Gill *et al*., 2001).

The widespread mortality of shisham trees in various ages (Baksha & Basak, 2000) was observed in Bangladesh and was presumed the source of disease may be *F. solani* and shothole borer. It is not possible either chemically or by crop rotation to remove pathogens from the soil (Bakshi, 1955). The fungicides of captaf (captan) and carbendazim (Bavistin) were found to be very successful against *F. solani* (Khan *et al*., 1965). Benomyl was found to be highly efficacious, leading to a substantial decrease in mycelial development, even at a very low dose of 10m, and ridomil was also efficient but at higher doses (Ahmad *et al*., 1996). Some other fungicides, such as Dithane M-45 and Vitavax, also had a substantial supressive effect on the development of *F. Solani*. (Bajwa & Javaid, 2007) demonstrate benomyl as the most efficient in invitro fungicide, may also be incredibly helpful to save shisham trees from wilting caused by *F. solani*.

Fig.4. Wilting of shisham tree (Source, Harsh, N. S. K. FRI Dehradun-248006)

Management of *Fusarium solani*

Consequently, management of sissoo wilt disease in plantations could be possible by increasing the soil moisture content by irrigation. The high soil moisture given by irrigation is associated with the decrease to a degree that is harmless to the crop of the soil of the fungus population. The soil should not be constantly underwater during irrigation, since aeration is necessary for the healthy growth of sissoo's roots (Bakshi, 1957). The *F. solani* control was highly effective with the application of Bavistin [carbendazim] and Captaf [captan] (Kumar, 1996). Studies in most of the cases in Nepal, illustrate the Bordeaux mixture (50% lime incorporated with 50% copper sulphate) paste is commonly used (Karki *et al*., 2000; Parajuli *et al*., 1999) Minimal causality was reported for soils manipulated with crop residues, including bean straw and sawdust (Kaushik *et al*., 1996). It is not feasible either chemically or by crop rotation to remove the pathogen from the soil. For the raising of healthy plantations free of wilting disease, the correct selection of the location with light-textured soil with sufficient soil humidity and good drainage is important (Tewari, 1994).

Dieback

Nepal is abundant in plant species with genetically diverse natural herbs. The geography and weather are wide-ranging (Prakash *et al*., 2020; Timilsina *et al*., 2020). A decline in sissoo is usually responsible for the decrease in growth, maturation, strength, and power. The plant's vigor, although the absolute loss of the tree crown is known as a dieback (Naqvi *et al*., 2019)

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The forest tree's dieback is a periodic phenomenon due to premature loss of tree health and vitality of the tree stand (Clatterbuck, 2006). The decline in forests and dieback from numerous forest ecosystems and climate zones around the world has been recorded (Lowman, 1991; Jump *et al*., 2006) and in many forest eco-types of the world, mortality rates have risen (Hosking, 1989). Dieback is an important challenge to this multifunctional tree (Ahmad *et al*., 2016; Ahmad *et al*., 2017) and millions of South Asian trees have been affected (Vogel *et al*., 2011). Symptoms of shisham dieback in southern Punjab of Pakistan are approximately close to mango dieback (Khan *et al*., 2014). The key causes for the tree decline and the dieback are climate change, fungal infections, and fertilizer inefficiencies (Simpson, 1993; Rajput *et al*., 2008). The causal species responsible for tree decline and the climate change often associated with forest dieback were identified in different regions of the world as fungal pathogens (Ahmad *et al*., 2016). The sissoo dieback is treated as a consequence of the pathogenic fungi, *G. lucidum*, *F. oxysporum*, *B. theobromae*, *F. solani*, and *P. cinnamomi* (Ahmad *et al*., 2013; Rajput *et al*., 2012; Gill *et al*., 2001; Harsh *et al*., 2010). The disease of dalbergia is caused by pathogenic bacteria, Pseudomonas, and Bacillus (Aktar *et al*., 2016).

Although a pathogenicity test to validate their function in die-back disease has not been discovered (Parajuli *et al*., 2000; Joshi & Baral, 2000). Sissoo-dieback causal agents are not yet found. Some connections between plant physiology and soil conditions, such as pH and soil nature (sandy alluvial or clay) irrigation, the water level of soil have nevertheless been identified *D. sissoo* dieback disease is potentially the ultimate cause of root decay occurring in a dying tree (FORESC, 1997). Dieback is a completely different disease. The dieback disease is accountable for both biotic and abiotic stress factors hindering the normal plant physiological operations (Basak *et al*., 2003), including pathogens and insects. Pathogens are vectors of biotic stress under severe conditions of temperature, drought, and waterlogging which are biotic agents of stress (Naz *et al*., 2015). Biotype and zonal environmental factors are linked with disease occurrence. Environmental pressures lead to tree mortality and forest diseases are expected to become more widespread and more serious in the immediate future due to various pathogens, given the increasing impact of climate change on different biotic and abiotic factors (Sturrock *et al*., 2011; Raza *et al*., 2015). However, the pathogenic isolates of *F. solani* have found high genetic diversity and are the leading cause of an outbreak and shisham dieback determination (Mukhtar *et al*., 2014). The fungal infection and the invasion of species as insects are secondary factors that influence the physiology of the sissoo leading to die-back (Ansari, 2000; Shah *et al*., 2020). Fungal infection and invasions by insects occur after environmental conditions degrade the plant (Negi *et al*., 1999).

Age is also a major factor in forest dieback growth. Trees are perennial, slowly growing woody trees, but they have a very higher mortality rate, even over a few months than their very fascinating growth rate (Nepstad *et al*., 2008). Older trees were more vulnerable than smaller trees to dieback (Auclair *et al*., 2010). There is little knowledge of the distribution and growth of the disease in individual forest trees of various ages (Timmermann *et al*., 2017). In older plants, ecological pressures quickly rupture membranes connected with the vessels and tracheids (Sperry *et al*., 1991). Mortality of over-mature dieback sissoo trees occurs within just a few weeks Acharya and Subedi (2000). Furthermore, tolerance for both abiotic and biotic stresses depends on the time, existence, and magnitude of each stress (K.C. *et al*., 2020). Along with the tree age, some fungi, more than 20 percent of older trees, have

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been damaged in abiotic stress of *D. sissoo* in Bihar (Chaturvedi *et al*., 2002). Dieback disease may be caused by root and stem-rotting parasites invading an aerial or underground segment of plants or both (Bagchee, 1945).

The wilt (*Fusarium solani*), the butt rot (*Ganoderma lucidum*), and *Polyporus gilvus*, commonly caused dieback infections. These fungi are correlated with the death of sissoo mortality (Sheikh, 1989; Bakshi, 1954). *Phytophthora sp.* is also responsible for root rot and Phytophthora vascular wilt by *Fusarium sp.* The fungi commonly arise from exposed areas of trees that are infected, e.g. by fungi, cut bark, pinholes, branch and root damage, etc. (Bakshi *et al*., 1959). The mycelia of these fungi grow into xylem and phloem, blocking water and sap to flows. The dieback symptoms are induced here. Trees will still survive if heartwood and sap-wood are killed (Bakshi *et al*., 1957)

Occurrence and symptoms of Dieback in Nepal

Shisham has been experiencing a decline or dieback in Asia a few years ago, and this incident was also recorded in Nepal, supposedly to be its home (Shah *et al*., 2010; Shrestha *et al*., 2008; Yadav, 2008). The first study on sissoo die-back in the plantations in Nepal was traced by (Baral, 1995) until 1993. Bajwa *et al*. (2003) recorded that the shisham tree has in recent years been affected by dieback and wilt diseases and a percentage of them is reported in the Terai tract in Nepal. This disease was registered in Kailali District in Nepal in 1989 at plantation locations (Thapa, 1990). Since then, almost all of Nepal's sissoo cultivation areas have seen this disease and have become an outbreak and are slowly spreading.

One of the most significant diseases is called dieback wilt by *F. Solani f. Sp. Dalbergiae* is eclipsed in *Dalbergia sissoo*. The dieback is distinguished by thinning leaves and crowns in extreme conditions, drying of ends of branches, roofing of table, and a stag-head (Khan & Khan, 2000). In the acropetal succession, the entire tree looks yellow, as shisham wilts yellowing and death of leaves occurs. The infected trees display symptoms of wilting, the leaf shed makes the branches clear in the advanced stages, and plants will eventually die in a few months (Kumar & Khurana, 2016). It can take one month to a year to fully die the tree from above; the tree begins to die from above (Parajuli *et al*., 1999).

Fig.5. *D. sissoo* showing symptoms of dieback. A. Adversely affected trees with stag head. B. Black spots on the bark (Muehlbach *et al*., 2010).

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Root disease and symptoms of Dieback in *D. sissoo* is given in Table 1.

Table1. Root disease and symptoms of Dieback.

S.N	Root diseases	Symptoms	Source
1.	Fusarium wilt	• yellowing and deaths of leaves in acropetal succession up the tree • fungal hyphae and jelly like substances plug the vessels	(Bakshi & Singh, 1959)
2.	Ganoderma Root Rot	• Sapwood white spongy rot • Fast pathogen dissemination, fast death.	(Champion & Seth, 1968)
3	Phellinus root and butt rot	• White rot in the sapwood and in the Heartwood. • Brown yellowish lower surface, bores round, dense dissipations.	(Bakshi, 1971; Bakshi,1976)
4	Root rot nematode	• galls on roots	(Mehrotra Sharma, 1992).
	Entomological Studies		
5	*Plecoptra reflexa*	• Removed from the leaves and defoliated leaf	(Bagchee 1945; Bakshi 1954)
6	*Dichomeris eridantis*	• Serious new and young plant defoliation	(Bagchee, 1945; Bakshi, 1954)
	Edaphic Conditions		
7	Water logged condition and heavy texture of soil	• asphyxiation of the roots	(Bakshi, 1957).

Management of dieback

Although it is still unknown what causes the die-back epidemic, a variety of remedial steps can still be taken to avoid or mitigate this disease and to prevent injury (Khan *et al*., 1965). Idrees *et al*. (2006) have undergone numerous chemical dieback management experiments. Various chemicals such as Scoral and Derosal, Topsin-M, Trimitox Forte, and Dithane M-45 can be used against fungal dieback. Additionally, sufficient agricultural technology, management experience, and accessibility to these chemicals will achieve proper outcomes (Tiwari *et al*., 2020; Tripathi *et al*., 2020). However, they documented no success when the rate of disease was above 25 percent. Consequently, an early diagnosis in a field and mitigation are the key to control dieback. When dieback signs are apparent in a tree, the disease progression cannot be prevented or reversed (Javaid *et al*., 2004). Fungicides such as Vitavax, Dithane M-45, Bavistin, and Benlate are often considered to have major suppressive consequences on the growth of *F. solani* (Ahmad *et al*., 1996). Different of biologist's experiments were performed to control die-back and mitigate the loss of shisham. The antagonistic effect of different fungal species namely *Trichoderma viride*, *T. koningii*, *T. pseudokoningii*, *T. areoviride*, *T. harzianum*, *Aspergillus fumigatus*, *A. oryzae*, and *A. glaucus* against dieback was studied by (Bajwa *et al*., 2004; BakShi, 1976)

The crop disease incidence in D. sissoo is given in Table 2.

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Table 2. Crop disease incidence in *D. sissoo* in respective countries

Country		Disease incidence (%)	Disease	Source
India (North Bihar)	Araria	80.0	Wilt, Die back	(Dayaram *et al*., 2003)
	Katihar	78.0		
	Darbhanga	35.4		
	Khagaria	41.6		
Panjab		80	Dieback	(Kumar, 2014)
Pakistan		60-80	Dieback, wilt, root rot	(Rajput *et al*., 2011)
Nepal		70-80	Dieback, wilt, root rot	(Acharya *et al*., 2000)
Bangladesh		60	Dieback, wilt	(Bhansli *et al*., 1997)

CONCLUSION

Many species of fungi such as *Fusarium solani*, *F. oxysporum*, *Ganoderma lucidum*, *Phellinus gilvus*, *Polypours gilvus*, *Rhizoctonia solani*, *Polyporus spongiosum*, are the reason of shisham decline. The principal reasons for tree wilting were linked with *F. Solani* fungus, *G. Lucidum* was responsible for extreme root rot, and the main cause of dieback is not yet comprehended. It can also be minimized by combining approaches such as root injury prevention, soil capacity enhancement by nutrient control, the avoidance of any harmful use of fungicide and chemical fertilizers, and the implementation of normal cultivation practices. In order to check the sources of pathogens and avoid further transmission of the disease, the dead, wilted, and die-back plants should be uprooted. To replace the susceptible varieties, new shisham nurseries should be raised from seeds and cuttings of the resistant variety. The appropriate use of chemical fungicides against tree diseases entails an understanding of the epidemiology of the disease. Understanding epidemic dynamics, including the life cycle of the pathogen, provides a framework for forecasting disease outbreaks. The decline of shisham is not just the concern of Nepal and India, but also the entire subcontinent of India, such as Myanmar, Pakistan, Bhutan, Bangladesh, Sri Lanka, etc. A strong interaction case by networking is, therefore, necessary on the international level for monitoring and combating this problem. Therefore, further study on the long-term surveillance and evaluation of root pathogens for multiple causes associated with the decrease in the shisham population is recommended.

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Authors' contributions

K. K. Shah conceptualized and wrote the whole manuscript. I. Tiwari, B. Modi, H. P. Pandey, S. Subedi and J. Shrestha added information, revised and finalized the paper.

Conflict of Interest

The authors declare that there is no conflict of interest regarding publication of this manuscript.

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