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DISEASES OF CONIFER SEEDLINGS CAUSED BY SEED-BORNE FUSARIUM SPECIES

R. L. James

ABSTRACT: The genus Fusarium includes many common soil-borne fungi that may colonize conifer seed, especially if cones are collected from the ground or squirrel caches. These fungi most commonly infect the seed coat, but can also colonize the seed embryo and endosperm. Fusarium spp. cause a wide variety of diseases, most of which affect the roots of susceptible plants. Types of diseases commonly affecting conifer seedlings in nurseries include (1) seed decay, (2) pre-emergence damping-off or germination failure, (3) postemergence damping-off, (4) topdamping-off or cotyledon blight, and (5) root diseases or late damping-off. The most common species of seed-borne fusaria include F. oxysporum, F. solani, F. moniliforme, and F. "roseum." Diseases caused by Fusarium can be reduced by seed treatments such as running water rinses, surface sterilants, and fungicides.

INTRODUCTION

Conifer seeds are storehouses of food and energy and many microorganisms have evolved mechanisms for invading and utilizing them. Many different fungi commonly infect conifer seeds. Infection frequently damages seed and also provides a means by which fungi may be transferred from one substrate or geographic location to another (Harman 1983).

Fusarium spp. are common soil-inhabiting plant pathogens (Booth 1971; Gerlach and Nirenberg 1982), which also frequently infect conifer seed (Neergaard 1977). These fungi attack a wide range of hosts and cause economically important diseases of many commercial crops, including conifer seedlings (Bloomberg 1971; Tint 1945). Fusarium spp. commonly occur within many types of soils. Populations frequently increase in cultivated soils (Booth 1971); low levels of these fungi often occur in undisturbed natural soils (Smith 1967).

Fusarium diseases of conifer seedlings have traditionally been most important in bareroot nurseries (Bloomberg 1971). Pathogen populations are often reduced in nursery soils by using fumigants such as methyl bromide and chloropicrin (Miller and Norris 1970). However, Fusarium-caused diseases sometimes occur despite soil fumigation (Cooley 1982). Investigations of diseases incited by Fusarium indicate that these fungi may be introduced into both bareroot and container nurseries on conifer seed, causing extensive losses (Cooley 1983b; Graham and Linderman 1983; James 1983a).

Although Fusarium spp. can infect conifer seed during flowering and cone formation, (Anderson and others 1980; Mason and Van Arsdel 1978; Sharma 1978), probably most infection occurs when cones or seed contact soil that harbors inoculum (James 1983c; Karrfalt 1983). Cones collected from squirrel caches often contain large populations of fungi including many pathogenic fusaria (James 1984c; James and Genz 1981; James and Genz 1982). During the seed extraction process, infection by fusaria may intensify (Salisbury 1955), resulting in both seedcoat and endosperm colonization (James 1984b; James 1984c). Diseases of seeds often increase during prolonged seed and cone storage (Bloomberg 1969; Harmon and others 1978; Harvey and Carpenter 1975). Seed colonization by pathogens can also increase during the extended seed stratification periods that are common in conifer nurseries (Bloomberg and Trelawny 1970).

TYPES OF DISEASES

Fusarium spp. cause several different kinds of diseases, the most important of which affect roots of susceptible plants (Booth 1971; Gerlach and Nirenberg 1982). Five types of diseases caused by these fungi are generally recognized on conifer seedlings. These include seed decay, pre-emergence damping-off or germination failure, postemergence damping-off, top damping-off or cotyledon blight, and root disease or late damping-off (Bloomberg 1971; Matuo and Chiba 1966).

Seed decay occurs when fungi penetrate the seedcoat, colonize it and break down internal seed contents (Bloomberg 1969). Seeds with damaged seedcoats are especially vulnerable to rapid fungal invasion (Gibson 1957; Neergaard 1977). Decayed seed may or may not be detectable from outward appearance (Bloomberg 1966). However, x-rays, which reveal hollow or partially deteriorated endosperms, can aid detection (Anderson and others 1980). Decayed seed may also be detected during water or air separation operations because of their reduced densities (James and Genz 1981; James and Genz 1982; Neergaard 1977). If decayed seed are sown, decreased germination will result and potentially pathogenic fungi are introduced into seedbeds or containers (James 1984a; Landis 1976a).

Pre-emergence damping-off occurs when the emerging radicle of germinating seed is attacked by fungi either carried on the seedcoat or present in soil (Bloomberg 1971; Graham and Linderman 1983). If the radicle is colonized by virulent fungi, decay results and no germinant emerges (Rathbun-Gravatt

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R. L. James is Plant Pathologist, Cooperative Forestry and Pest Management, USDA Forest Service, Missoula, MT.

1931). Most losses to pre-emergence damping-off are never detected and are often attributed to "bad seed." Investigations of nonemergence of germlings are usually necessary to determine if pathogenic fungi are involved.

Postemergence damping-off refers to disease of newly emerged germinants. Lesions often appear at the ground line, causing infected germinants to fall over (Bloomberg 1971; Landis 1976a). Decay of the germinant follows and sporulation may occur on decayed tissues. Seed-borne fusaria may incite postemergence damping-off, resulting in reduced seedling densities (Graham and Linderman 1983; Matuo and Chiba 1966; Urosevic 1961).

Top damping-off caused by Fusarium spp. occurs as colytedon blight (Mason and van Arsdel 1978), hypocotyl rot (Brownell and Schneider 1983; Hamm, personal communication), or stem rot (Morgan 1983). Cotyledon blight is especially common on pine species that retain their seedcoats on the tips of cotyledons for extended periods after germination (Mason and van Arsdel 1978). Seed-borne fusaria move from attached seedcoats and colonize cotyledons, causing decay and eventual mortality. Hypocotyl and stem rots are caused by either natural populations of soil-borne fusaria or pathogens introduced on infected seed.

Root disease caused by Fusarium usually occurs on seedlings that are several months old. Disease results from decay of feeder roots (Pawuk and Barnett 1975); affected seedlings become slow growing and chlorotic (Landis 1976b) and may develop wilt symptoms and needle tip dieback (James 1983a; James 1984c; James 1984d). Seedling deterioration may occur either gradually or rapidly (Merrill and others 1981). The disease may cause seedling mortality or reduced seedling vigor, which adversely affect outplanting survival (LaMadeleine 1979). Seedlings may become infected during or shortly after establishment, but infecting fungi may remain inactive for several months (Bloomberg 1966). When seedlings become stressed during crown closure, periods of heat or moisture stress, or during hardening off, the infecting fungi may become active and induce disease (James 1984c; James 1984d). Another possibility is that soil-borne fusaria may become more pathogenic when seedlings are stressed. In any event, losses from root disease can continue for several months in containerized stock (James 1983c; Landis 1976b) and throughout the first and second growing seasons in bareroot stock (James 1983b; James 1983d).

SPECIES OF FUSARIUM

The most common species of Fusarium isolated from conifer seed is F. oxysporum Schlect. (Graham and Linderman 1983; James 1984b; James 1983c; James and Genz 1982). This fungus is an important seed- or soil-borne pathogen of many different plants including conifer seedlings (Booth 1971; Cooley 1983a; Gerlach and Nirenberg 1982). It is capable of causing vascular wilts (Booth 1971; Neergaard 1977) and cortical rots of seedling stems (Brownell and Schneider 1983; Morgan 1983) and roots (James 1984b; James 1983d). Although F. oxysporum exhibits a wide host range (Booth 1971; Gerlach and Nirenberg 1982) individual strains of the fungus, called formae specialis (f. sp.), usually infect only a few selective hosts (Gordon 1965; Snyder and Hansen 1940). Only one f. sp. (designated pini) is usually recognized for isolates of F. oxysporum that attack conifers (Gordon 1965).

Isolates that cause diseases of conifers are generally not thought to infect other plant species (Brownell and Schneider 1983). However, responses of different conifer species to infection by several F. oxysporum isolates have sometimes been sufficiently variable to indicate that designation of additional f. sp. (other than pini) which attack conifers might be warranted (James and Gilligan 1984; Matuo and Chiba 1966). Additional pathogenicity tests on a wide range of conifer hosts will be needed to help clarify this issue. Pathogenic isolates of F. oxysporum have been obtained from conifer seed (Graham and Linderman 1983). However, nonpathogenic isolates have also been frequently isolated. Therefore, occurrence of F. oxysporum on seed does not necessarily mean that disease will result (James 1984a; James and Genz 1982).

Another Fusarium species commonly isolated from conifer seed is F. solani (Mart.) Sacc. (James 1983a; James 1983c; James 1984a). It is a common root decay organism that is especially damaging on certain agricultural crops (Booth 1971; Gerlach and Nirenberg 1982; Neergaard 1977). The fungus is occasionally associated with diseases of conifer seedlings (Landis 1976b; Merrill and others 1981; Tint 1945). However, the pathogenic potential of seed-borne sources of this fungus is unclear for conifer seedlings.

Other species of Fusarium frequently isolated from conifer seed include F. moniliforme Sheldon and F. roseum (Lk.) Sacc. (James 1983c; James 1983e; James 1984a; James and Genz 1982). Fusarium moniliforme causes root decay in several types of plants (Booth 1971; Gerlach and Nirenberg 1982), but is infrequently associated with conifer diseases (James 1984a; Rowan 1982). Fusarium roseum is actually a complex of organisms that produce distinctive pigments in culture (Booth 1971). Members of this group are frequently isolated from conifer seed (James 1983c; James 1983e; James and Genz 1981) and less frequently from diseased seedlings (James 1983e; James 1984d; Morgan 1983). Although some of these fungi may be pathogenic (James and Gilligan 1984; Morgan 1983), most are saprophytic (Booth 1971; Gerlach and Nirenberg 1982). Seed-borne isolates of F. roseum have generally not been evaluated for their pathogenic potential.

DISEASE CONTROL

The extent of Fusarium contamination on seed varies greatly among conifer species and seedlots (James 1984a; James and Genz 1982). Differences among seedlots may be related to cone collection, storage, and seed extraction practices. Cones collected from squirrel caches often have high levels of fungal contamination. Also, cones and seed stored under damp conditions for longer time periods are more prone to damage by fungi.

Seed treatment before sowing may reduce disease losses caused by seed-borne fusaria (Johnson and Harvey 1975; Johnson and Linton 1942). Most growers soak seed in water to condition them for sowing; some use standing water and others a running water rinse (James 1984a). If infected seed is soaked in standing water, fungal propagules can spread, causing widespread infection (James 1983e). However, placing seed under a running water rinse can reduce seedcoat contamination and does not spread infection (James 1983e; James 1984a).

Surface sterilants, such as hydrogen peroxide and sodium hypochlorite (commercial bleach), have frequently been used to reduce fungal contaminations and enhance germination of conifer seed (Advincula and others 1983; James and Genz 1981). Hydrogen peroxide usually reduces or eliminates fungal contaminants (Barnett 1976; James and Genz 1981). The effect of hydrogen peroxide on conifer seed germination has been variable. For example, some investigators (Edwards and Sutherland 1979; James 1983a) report reduced seed germination; others (Ching and Parker 1958; James and Genz 1981; Mason and van Arsdel 1978) report improved germination. Detrimental effects of H_2O_2 generally increase with chemical concentration and exposure period. Sodium hypochlorite usually reduces fungal contamination (James and Genz 1981) and sometimes enhances seed germination (Advincula and others 1983).

Several fungicides have been used for seed treatments to reduce damping-off caused by seed-borne pathogens (Mittal and Sharma 1981; Strong 1952); however, reports of fungicide toxicity to seed and germinants have limited their use (Cooley 1983a; James 1983e; Lock and others 1975). For example, use of captan has resulted in reduced seed germination (Peterson 1970), and has caused seedling injury following germination (Cayford and Waldron 1967; Lock and others 1975). Thiram, another common seed-treatment fungicide, has reduced seed germination (Dick and others 1958; Shea 1959) and caused deformed germinants (Hedderwick and Gadgil 1966). Effectiveness of seed-treatment fungicides is apparently related to dosage levels (Hamilton and Jackson 1951), activity spectrum against target organisms, development of resistant fungal strains, and persistence on seed (Sutherland and van Eerden 1980).

CONCLUSIONS

1. The genus *Fusarium* causes a wide variety of diseases of conifer seedlings.

2. Several *Fusarium* spp. have been shown to be carried both externally and internally by conifer seed.

3. The best method to reduce *Fusarium* contamination of seed is unclear, although running water rinses may be effective.

4. Seedlots of susceptible species should be bioassayed for presence of *Fusarium* after extraction to identify problem lots.

RESEARCH NEEDS

Effects of cone collection, storage, and seed handling techniques on disease caused by seed-borne fusaria need investigation. Several pertinent questions need to be answered, for example, should squirrel cache collections be permitted for susceptible species, and should cones be stored under specific conditions to reduce spread of *Fusarium*? What are the best temperatures and seed moisture levels for storage of *Fusarium*-infested seedlots? Should infested seedlots be stratified? Will stratification improve or reduce germination?

Another important research need concerns taxonomy of *F. oxysporum* strains that cause diseases of conifer seedlings. Pathogenicity tests on a wide range of conifer hosts are needed to determine host specificity characteristics of fungal strains.

REFERENCES

Advincula, B. A.; Woo, J. Y.; Partridge, A. D. A method for germination of western white pine seeds. Moscow, ID: University of Idaho; 1983; 4 p. Unpublished report.

Anderson, R. L.; Belcher, E.; Miller, T. Occurrence of internal seed fungi in slash pine seed produced in seed orchards. Atlanta, GA: U. S. Department of Agriculture, Forest Service, Southeastern Area, State and Private Forestry; 1980; Rept. 81-1-4; 3 p.

Barnett, J. P. Sterilizing southern pine seeds with hydrogen peroxide. Tree Planters' Notes. 27(3): 17-19; 1976.

Bloomberg, W. J. The occurrence of endophytic fungi in Douglas-fir seedlings and seeds. Can. J. Bot. 44: 413-420; 1966.

Bloomberg, W. J. Disease of Douglas-fir seeds during cone storage. Forest Science. 15: 176-181; 1969.

Bloomberg, W. J. Diseases of Douglas-fir seedlings caused by *Fusarium oxysporum*. Phytopathology. 61: 467-470; 1971.

Bloomberg, W. J.; Trelawny, J. Effect of thiram on germination of Douglas-fir seed. Phytopathology. 60: 1111-1116; 1970.

Booth, C. The genus *Fusarium*. Kew, Surrey, England: Commonwealth Mycological Institute; 1971. 237 p.

Brownell, K. H.; Schneider, R. W. Fusarium hypocotyl rot of sugar pine in California. Plant Disease. 67: 105-107; 1983.

Cayford, J. H.; Waldron, R. M. Effects of captan on germination of white spruce, jack and red pine seed. For. Chron. 43: 381-384; 1967.

Ching, T. M.; Parker, M. C. Hydrogen peroxide for rapid viability tests of some coniferous tree seeds. For. Sci. 4: 128-134; 1958.

Cooley, S. J. Evaluation of the fungicide Banrot to prevent root rot of sugar pine seedlings. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1982. 10 p.

Cooley, S. J. Fungicide trials on sugar pine at a southern Oregon nursery. Tree Planters' Notes. 34(3): 15-18; 1983a.

Cooley, S. J. Seed and soil treatments to reduce seed decay and Fusarium root rot of sugar pine. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1983b; 8 p.

Dick, J.; Finnis, J. M.; Hunt, L. O.; Kverno, N. B. Treatment of Douglas-fir seed to reduce loss to rodents. J. Forestry. 56: 660-661; 1958.

Edwards, D. G. W.; Sutherland, J. R. Hydrogen peroxide treatment of Abies seeds. Can. For. Ser. Bi-monthly Res. Notes 35: 3-4; 1979.

Gerlach, W.; Nirenberg, H. The genus Fusarium - a pictorial atlas. Berlin, Germany: Paul Parey; 1982. 406.

Gibson, I. A. S. Saprophtic fungi and destroyers of germinating pine seeds. East African Agri. J. 22: 203-206; 1957.

Gordon, W. L. Pathogenic strains of Fusarium oxysporum. Can. J. Bot. 43(11): 1309-1318; 1965.

Graham, J. H.; Linderman, R. G. Pathogenic seed-borne Fusarium oxysporum from Douglas-fir. Plant Disease. 67: 323-325. 1983.

Hamilton, J. R.; Jackson, L. W. R. Treatment of shortleaf pine and loblolly pine seed with fungicidal dusts. Plant Dis. Reptr. 35: 274-276; 1951.

Hamm, P. B. Personal communication. Corvallis, OR: Oregon State University, Department of Botany and Plant Pathology: 1985, February 13.

Harman, G. E. Mechanisms of seed infection and pathogensis. Phytopathology. 73: 326-329; 1983.

Harman, G. E.; Nedrow, B.; Nash, G. Stimulation of fungal spore germination by volatiles from aged seeds. Can. J. Bot. 56: 2124-2127; 1978.

Harvey, G. M.; Carpenter, L. R. Fungi on stored Douglas-fir cones - a problem? Tree Planters' Notes. 26(4): 16-17, 22: 1975.

Hedderwick, G. W.; Gadgil, P. D. Effects of fungicidal treatment on Pinus radiata seed. New Zealand For. Res. Inst.; 1966; Ann. Rept., p. 34-35.

James, R. L. Fusarium root disease of containerized seedlings at the Montana State Nursery, Missoula. Missoula, MT: U. S. Department of Agriculture, Forest Service, Northern Region; 1983a. 9 p.

James, R. L. Fusarium root disease of western white pine seedlings at the Coeur d'Alene Nursery, Missoula, MT: U. S. Department of Agriculture, Forest Service, Northern Region; 1983b. 5 p.

James, R. L. Fungal contamination of ponderosa pine cones and seed from the Coeur d'Alene Nursery, Idaho. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region; 1983c. 6 p.

James, R. L. Mortality of white fir seedlings at the Fantasy Farms Nursery, Peck, Idaho. Missoula, MT: U. S. Department of Agriculture, Forest Service, Northern Region; 1983d. 7 p.

James, R. L. Occurrence of Fusarium on Douglas-fir seed from the Montana State Nursery. Missoula, MT: U. S. Department of Agriculture, Forest Service, Northern Region; 1983e. 11 p.

James, R. L. Diseases associated with containerized seedling soil mixes. Missoula, MT: U. S. Department of Agriculture, Forest Service, Northern Region; 1984a. 7 p.

James, R. L. Fungi colonizing Douglas-fir seed at the Champion Timberlands Nursery, Plains, Montana. Missoula, MT: U. S. Department of Agriculture, Forest Service, Northern Region; 1984b; Rept. 84-13. 3 p.

James, R. L. Needle tip dieback of containerized Douglas-fir seedlings at the Coeur d'Alene Nursery, Idaho. Missoula, MT: U. S. Department of Agriculture, Forest Service, Northern Region; 1984c. 5 p.

James, R. L. Tip dieback of containerized Douglas-fir seedlings at the Montana State Nursery, Missoula. Missoula, MT: U. S. Department of Agriculture, Forest Service, Northern Region; 1984d. 6 p.

James, R. L.; Genz, D. Ponderosa pine seed treatments: effects on seed germination and disease incidence. Missoula, MT: U. S. Department of Agriculture, Forest Service, Northern Region; 1981: Rept. 81-16; 13 p.

James, R. L.; Genz D. Evaluation of fungal populations on ponderosa pine seed. Missoula, MT: U. S. Department of Agriculture, Forest Service, Northern Region; 1982; Rept. 82-22, 21 p.

James, R. L.; Gilligan, C. J. Studies of Fusarium associated with containerized conifer seedling diseases: pathogenicity tests of isolates from the Alpine Nursery, Kalispell, Montana. Missoula, MT: U. S. Department of Agriculture, Forest Service, Northern Region; 1984; Rept. 84-14. 29 p.

Johnson, D. W.; Harvey, R. D. Seed protectant fungicides for control of Douglas-fir and ponderosa pine seedling root rots. Tree Planters' Notes. 26(2): 3-5; 1975.

Johnson, L. P. V.; Linton, G. M. Experiments on chemical control of damping-off in Pinus resinosa seedbeds. Can. J. Res. C. 20: 559-571; 1942.

Jones, L. Germination of repellent-treated southern pine seed before and after storage. Res. Note SE-15. Asheville, NC: U. S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1963. 4 p.

Karrfalt, R. P. Fungus-damaged seeds can be removed from slash pine seedlots. Tree Planters' Notes. 34(2): 38-39; 1983.

LaMadeleine, L. A. Evaluation of 3-0 and 4-0 red pine in Eveleth Nursery, Minnesota, 1979. Broomall, PA: U. S. Department of Agriculture, Forest Service, Northeastern Area, State and Private Forestry; 1979; Rept. NA-TP-2. 4 p.

Landis, T. D. An analysis of seed and seedling losses at Mt. Sopris Tree Nursery. Lakewood, CO: U. S. Department of Agriculture, Forest Service, Rocky Mountain Region; 1976a; Bio. Eval. R2-76-18. 13 p.

Landis, T. D. Fusarium root disease of containerized tree seedlings - Colorado State Forest Service Nursery. Lakewood, CO: U. S. Department of Agriculture, Forest Service, Rocky Mountain Region; 1976b; Bio. Eval. R2-76-16. 6 p.

Lock, W.; Sutherland, J. R.; Sluggett, L. J. Fungicide treatment of seeds for damping-off control in British Columbia forest nurseries. Tree Planters' Notes. 26(3): 16-18; 1975.

Mason, G. N.; Van Arsdel, E. P. Fungi associated with Pinus taeda seed development. Plant Dis. Reptr. 62: 864-867; 1978.

Matuo, T.; Chiba, O. Species and formae specialis of Fusaria causing damping-off and root rot of coniferous seedlings in Japan. Ann. Phytopath. Soc. Japan 32: 14-22; 1966.

Merrill, W.; McCall, K; Zang, L. Fusarium root rot of Douglas-fir and Fraser fir seedlings in Pennsylvania. Plant Disease. 65: 913-914. 1981.

Miller, W. O.; Norris, M. G. A new review of soil fumigation practices for use in forest nurseries. Down to Earth. 26(3): 9-12; 1970.

Mittal, R. K.; Sharma, M. R. Evaluation of fungicides to control some common seed-borne fungi. Indian Forester. 35: 589-591; 1981.

Morgan, P. Fusarium stem rot of Douglas-fir seedlings. Plant Disease. 67: 441-442; 1983.

Neergaard, P. Seed pathology. New York: John Wiley & Sons; 1977. 1187 p.

Pawuk, W. H.; Barnett, J. P. Root rot and damping-off of container-grown southern pine seedlings. In: Tinus, R. W., Stein, W. I., Balmer, W. E., eds. North American containerized forest tree seedling symposium: proceedings; 1974. Denver, CO; Great Plains Agr. Council Pub. No. 68; 1975: 173-176.

Peterson, G. W. Seed-protectant chemicals affect germination of ponderosa pine seed. Tree Planters' Notes. 21(4): 25-29; 1970.

Rathbun-Gravatt, A. Germination loss of coniferous seeds due to parasites. J. Agric. Res. 42: 71-92; 1931.

Rowan, S. J. Tip dieback in southern pine nurseries. Plant Disease. 66: 258-259; 1982.

Salisbury, P. J. Moulds of stored Douglas-fir seed in British Columbia. Victoria, B.C.: Canadian Department of Agriculture Forest Biology Division; 1955; Interim Rept. 10 p.

Sharma, A. D. Fungi associated with conifer (Pinus roxiburgii) seeds. Indian J. Mycol. and Plant Pathol. 10(1): 106-107; 1978.

Shea, K. R. Phytotoxicity of thiram to Douglas-fir seed. Weyerhaeuser Timber Co., For. Res. Note 21; 1959. 5 p.

Smith, R. S., Jr. Decline of Fusarium oxysporum in the roots of Pinus lambertiana seedlings transplanted into forest soils. Phytopathology. 57: 1265; 1967.

Snyder, W. C.; Hansen, H. N. The species concept in Fusarium. Am. J. Bot. 27(2): 64-67; 1940.

Strong, F. C. Damping-off in the forest tree nursery and its control. Mich. Agr. Exp. Sta. Quart. Bull. 34: 280-296; 1952.

Sutherland, J. R.; Van Eerden, E. Diseases and insect pests in British Columbia forest nurseries. British Columbia Ministry of Forests, Canadian Forestry Service; 1980; Joint Report No. 12. 55 p.

Tint, H. Studies in the Fusarium damping-off of conifers. I. The comparative virulence of certain Fusaria. Phytopathology. 35: 421-439; 1945.

Urosevic, B. The influence of saprophytic and semiparasitic fungi on the germination of nursery spruce and Scots pine seeds. Proc. Int. Seed Test. Assoc. 26. 537-556; 1961.