Occurrence of *Fusarium* on Conifer Tree Seed from Northern Rocky Mountain Nurseries[1]

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Fusarium spp. are common colonizers of conifer seed from northern Rocky Mountain nurseries. Assays of ponderosa pine, Douglas-fir, western larch, and spruce seeds indicate great variability in extent of contamination among seedlots. In some spruce seedlots almost 90 percent of the seeds tested were colonized by *Fusarium*; most seedlots of other species were much less contaminated. Fusaria are commonly found both on the seedcoat and within the endosperm of colonized seed. Seven species of *Fusarium* have thus far been isolated from seed, although *F. oxysporum* was encountered most frequently. Types of diseases associated with seedborne fusaria and techniques used to reduce levels of seed contamination are discussed.

INTRODUCTION

Investigations of diseases incited by *Fusarium* spp. indicate that these fungi are often introduced into both bareroot and container nurseries on conifer seed, sometimes causing extensive losses (Cooley 1983; Graham and Linderman 1983; James 1983b). Although *Fusarium* can infect conifer seed during flowering and cone formation (Anderson et al. 1980; Mason and Van Arsdel 1978; Sharma 1978), probably most infection occurs when cones or seed contact soil that harbors inoculum (James 1983a; Karrfalt 1983). Cones collected from squirrel caches often contain large populations of fungi including many pathogenic fusaria (James 1984b; James and Genz 1981; James and Genz 1982). During seed extraction, infection by *Fusarium* may intensify (Salisbury 1955), resulting in both seedcoat and endosperm colonization (James 1984a; James 1984b). Seedborne diseases often increase after prolonged seed and cone storage (Bloomberg 1969; Harman et al. 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).

OCCURRENCE ON SEED

Investigations to elucidate the role of seedborne *Fusarium* spp. as incitants of disease in northern Rocky Mountain Nurseries began in 1981 (James and Genz 1981). Most evaluations have involved incubating seed from representative lots on a selective agar medium for *Fusarium* (Komada 1975). Placing seed directly on the medium gives an indication of abundance of *Fusarium* on the seedcoat. By aseptically dissecting seed and carefully separating the seedcoat from the endosperm, abundance of *Fusarium* on these two components can be determined.

Results of investigations to determine abundance of *Fusarium* on or within conifer seed are summarized in table 1. Many of these investigations have dealt with Douglas-fir (*Pseudotsuga menziesii* Dougl.)

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[1]Paper presented at the Western Forest Nursery Council Meeting, Tumwater, WA, August 12-15, 1986.
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seed since disease incidence is usually most noticeable and widespread on this species, especially in container operations. Other species investigated include ponderosa pine (*Pinus ponderosa* Laws.), western larch (*Larix occidentalis* Nutt.), blue spruce (*Picea pungens* Engelm.) and Black Hills spruce (*P. glauca* var. *albertiana* (S. Brown) Sarg.). Results indicate that, in general, great variation exists in the occurrence of *Fusarium* among tested lots. Also, most lots tested have evidence for *Fusarium* within the endosperm as well as on the seedcoat, indicating either infection during seed formation or penetration of the seedcoat by the fungus.

As yet there have been no studies which have statistically evaluated the correlation between amount of seed infection and subsequent disease incidence. However such a correlation would be expected, since experience indicates that seedlots with poor germination and seedling emergence are generally infested by *Fusarium* to a greater extent than lots with better germination (James, unpublished).

TYPES OF DISEASES

Five types of diseases caused by seedborne fusaria are generally recognized on conifer seedlings. These include seed decay, pre-emergence damping-off or germination failure, post-emergence 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). If decayed seed are sown, decreased germination will result and potentially pathogenic fungi introduced into seedbeds or containers (James 1985a; Landis 1976a). Pre-emergence damping-off occurs when the emerging radicle of germinating seed is attacked by fungi carried either on the seedcoat or present in soil (Bloomberg 1971; Graham and Linderman 1983). If the radicle is colonized by pathogenic fungi, decay results and no germinant emerges (Rathbun-Gravatt 1931). Post-emergence damping-off refers to disease of newly emerged germinants in which lesions often appear at the ground line, causing infected germinants to fall over (Bloomberg 1971; Landis 1976a). Decay of the germinant follows and sporulation of fungi may occur on decayed tissues. Top damping-off caused by *Fusarium* occurs as cotyledon blight (Mason and van Arsdel 1978), hypocotyl rot (Brownell and Schneider 1983), or stem rot (Morgan 1983). Cotyledon blight is especially common on species, such as ponderosa pine and Douglas-fir, which retain their seedcoats on the tips of cotyledons for extended periods after germination (Mason and van Arsdel 1978). Root disease caused by seedborne fusaria 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 1983b; James 1984b; James 1984c). This disease may cause seedling mortality or reduced seedling vigor, which adversely affects outplanting survival (LaMadeleine 1979).

SPECIES OF FUSARIUM

Seven species of *Fusarium* have thus far been isolated from conifer seed at northern Rocky Mountain nurseries (table 1). The most common species isolated is *F. oxysporum* Schlect., an important pathogen of many different plants including conifer seedlings (Booth 1971; Cooley 1983; 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 1983c; James 1984a). 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*) has thus far been recognized for isolates that attack conifers (Gordon 1965). However, responses of different conifers 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.

Another *Fusarium* species commonly isolated from conifer seed is *F. solani* (Mart.) Sacc. (table 1). It is a commmon root decay organism that is especially damaging on agricultural crops (Booth 1971; Gerlach and Nirenberg 1982; Neergaard 1977). The fungus is occasionally associated with diseases of conifer seedlings (Landis 1976b; Merrill et al. 1981; Tint 1945). However, the pathogenic potential of seedborne sources of this fungus is unclear for conifer seedlings.

Table 1.—Abundance of Fusarium spp. on conifer seed from Northern Rocky Mountain Nurseries.

Species[1]	Nursery[2]	No. lots sampled	Percent lots w/Fusarium	Percent seed w/Fusarium Seedcoat	Percent seed w/Fusarium Endosperm	Associated Fusarium species[3]	Reference
PP	CDA	1	100	4–12	4–20	FOXY	James 1986c
PP	MSN	1	100	2–4	—	FSAM; FACU; FSPO	James 1985b
PP	CTN	8	75	0–8	—	FOXY; FSOL	James & Genz 1982
PP	CTN	2	100	—	—	FOXY	James & Genz 1981
DF	CDA	5	100	1–22	2–8	FOXY; FAVE	James (unpub. 1986)
DF	UIN	3	100	6–43	—	—	James & Dumroese (unpub. 1986)
DF	CDA	5	80	0–10	—	FOXY; FSOL	James 1983d
DF	PCN	4	75	0–7	—	FOXY; FACU	James 1986a
DF	CTN	4	75	0–13	—	FOXY; FSOL	James 1984a
DF	MSN	1	100	4	4	FOXY; FSOL	James 1983b
WL	NN	2	100	5–88	—	FOXY; FSAM	James 1986b
BS	TN	5	100	0–52	—	FOXY; FSOL; FTRI	James 1985c
BHS	TN	3	100	18–78	—	FOXY; FSOL; FTRI	James 1985c

[1]PP = ponderosa pine; DF = Douglas-fir; WL = western larch; BS = blue spruce; BHS = Black Hills spruce

[2]CDA = USDA Forest Service Nursery, Couer d'Alene, ID; MSN = Montana State Nursery, Missoula, MT; CTN = Champion Timberlands Nursery, Plains, MT; UIN = University of Idaho Nursery; Moscow, ID; PCN = Plum Creek Nursery, Pablo, MT; NN = Nishak Nursery, Bonners Ferry ID; TN = North Dakota Forest Service Nursery, Towner, ND.

[3]FOXY = F. oxysporum; FSAM = F. sambucinum; FACU = F. acuminatum; FSPO = F. sporotrichiodes; FSOL = F. solani; FAVE = F. avenaceum; FTRI = F. tricinctum.

Other species of Fusarium isolated from conifer seed include F. acuminatum Ell. & Ev., F. avenaceum (Fr.) Sacc., F. sambucinum Fuckel, F. sporotrichioides Sherb., and F. tricinctum (Corda) Sacc. (table 1). Although some of these fungi are pathogenic (James 1985c; James and Gilligan 1984), many are probably saprophytic (Booth 1971; Gerlach and Nirenberg 1982). Many seedborne isolates of these fungi need to be evaluated for their pathogenic potential.

DISEASE CONTROL

The extent of Fusarium contamination on seed varies great among different conifer species and seedlots (table 1). These differences may be related to cone collection, storage, and seed extraction practices. For example, 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 seedborne 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 1983b). However, placing seed under a running water rinse can reduce seedcoat contamination and does not spread infection (James 1983b; James 1984a).

Sterilants such as hydrogen peroxide and sodium hypochlorite (commercial bleach) have frequently been used to reduce fungal contamination and enhance germination of conifer seed (James and Genz 1981; Partridge et al. 1985). Hydrogen peroxide usually reduces or eliminates fungal contaminants (Barnett 1976; James and Genz 1981). The effect of hydrogen peroxide on seed germination has been variable. For example, some investigators (Edwards and Sutherland 1979; James 1983b) report reduced seed germination, whereas others (Ching and Parker 1958; James and Genz 1981; Mason and van Arsdel 1978) report improved germination. Detrimental effects of hydrogen peroxide generally increase with chemical concentration and exposure period. Sodium hypochlorite usually reduces fungal contamination (James and Genz 1981) and sometimes enhances seed germination (Partridge et al. 1985).

Several fungicides have been used for seed treatments to reduce damping-off caused by seedborne pathogens (Mittal and Sharma 1981; Strong 1952). However, reports of fungicide toxicity to seed and germinants have limited their use (Cooley 1983; James 1983b; Lock et al. 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 et al. 1975). Thiram, another common seed-treatment fungicide, has reduced seed germination (Dick et al. 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).

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