Damping-Off

Michelle M. Cram

Plant Pathologist, USDA Forest Service, Forest Health Protection, Athens, GA

Damping-off is a disease of germinating and newly emerged conifer and hardwood seedlings that causes decay of succulent tissue, wilting, and seedling mortality. Many species of pathogenic fungi can cause damping-off. Some of the factors influencing damping-off include pathogen populations, host susceptibility, and soil temperature, moisture, and pH. The severity of damping-off can vary from field to field and year to year depending on these factors. Managers can reduce damping-off losses in nursery beds with an integrated program of cultural and chemical practices. Tree Planters' Notes 50(1): 9-13; 2003.

Distribution and Hosts

Damping-off is one of the most common disease problems causing seedling losses in North American forest nurseries (Sutherland 1984; Cram and Fraedrich 1996). Although damping-off is often reported by nursery managers to be a slight problem (Sutherland 1984; Cram and Fraedrich 1996), under conditions favorable to disease development, damping-off can have a severe impact on seedling density and final inventory (Boyce 1961). In North America, most conifers and hardwoods are susceptible to damping-off (Filer and Peterson 1975). Some tree species are partially resistant, such as seedlings in the cypress (Cupressaceae) family (Hartley 1921); northern catalpa *(Catalpa speciosa* (Warder) Warder ex Engelm.), hackberry (Celtis occidentalis L.), green ash *(Fraxinus pennsylvanica* Marsh. var. *lanceolata* (Borkh.) Sarg.), honeylocust *(Gleditsia triacanthos L.),* and bur oak *(Quercus macrocarpa* Michx.) (Wright 1944; Filer and Peterson 1975).

Pathogens

Damping-off is caused by various pathogenic fungi that infect seedlings during germination and after emergence when the seedling tissue is succulent. Four to 6 wk after emergence, the seedlings develop woody tissue and the susceptibility to damping-off fungi quickly declines (Roth and Riker 1943c; Tint 1945). The fungi that cause damping-off vary depending on the host and location. The most common damping-off fungi are species in the genera *Pythium, Rhizoctonia, Fusarium,* and *Phytophthora* (Roth and Riker 1943a; Boyce 1961; Vaartaja 1964; Filer and Peterson 1975; Kelley and Oak 1989; Russell 1990). Other fungi that occasionally cause damping-off include *Cylindrocladium spp., Botrytis cinerea* Pers., *Sphaeropsis sapinea (Fr.)* Dyko and Sutton (Fisher 1941), *Macrophomina phaseolina* (Tassi) Goid. (Boyce 1961), *Alternaria alternata (Fr.)* Keissler, *Cladosporium cladosporioides* (Fres.) de Vries, *Penicillium expansion* Link (Huang and Kuhlman 1990), and *Phoma* spp. (Russell 1990). Many of these fungi are weak pathogens that invade the succulent tissue of germinating seedlings under environmental conditions that favor the pathogen (Boyce 1961) and reduce early seedling growth and vigor (Filer and Peterson 1975). These fungi can be present in soil and organic matter (Filer and Peterson 1975; Huang and Kuhlman 1990) and on seeds (Fisher 1941; Huang and Kuhlman 1990). Sterilized or fumigated soil can be recolonized by damping-off fungi that have been carried by wind on soil particles or by contaminated water, equipment (Vaartaja 1967), mulch, and seed.

Symptoms

Preemergence damping-off occurs when fungi infect developing radicals and kill seedlings while shoot tissues are still below ground (Filer and Peterson 1975). Random pockets of poor seedling emergence are an indication of preemergence damping-off. However, other problems can cause similar effects, including nonuniform seeding of containers or beds, poor seed development, seed decay, and removal of mulch or soil by wind and rain.

Postemergence damping-off occurs when fungi infect the succulent tissue of germinants with aboveground shoots, causing decay, wilting, and mortality (Boyce 1961). Infection occurs on the stem at or slightly below the groundline (Wright 1944; Filer and Peterson 1975) and on the roots (Hartley 1921). The infected tissue appears as a purple-to-brown lesion or as a dark water-soaked area that becomes sunken or constricted. In conifers, postemergence damping-off results in wilting and collapse of the seedling (Boyce 1961; Filer and Peterson 1975). Hardwood seedlings often remain upright as they wilt until the stem breaks off or rots away (Wright 1944).

Postemergence damping-off lesions may be confused with heat lesions (Hartley 1918). Heat lesions develop just above the groundline, are usually whitish, and are often located on 1 side of the stem in the early stage (Hartley 1918). The occurrence of heat lesion damage is scattered throughout nurseries and is dependent on pat-

***Figure 1-An** expanding patch of postemergence damping-off* (Fusarium oxysporum *Schlect. emend. Snyd. & Hans.) in black cherry* (Prunus *serotina Ehrh.) seedlings.*

terns of shade and heat buildup (Hartley 1921), while damping-off often occurs in expanding patches (figure 1).

Disease Development

Damping-off can cause significant losses in a nursery one year and minor losses the next (Hartley 1921). The susceptibility of seedlings and the activity of dampingoff fungi are affected by climatic variations, and this results in irregular losses and poor correlation of losses with soil fungal populations (Wright 1945). Other factors affecting damping-off losses include the presence of microorganisms antagonistic to pathogenic fungi (Hartley 1921; Roth and Riker 1943b; Huang and Kuhlman 1991), poor soil fumigation and rapid recolonization by damping-off fungi (Vaartaja 1967), and variation in pathogenicity within fungal species (Hartley 1921; Tint 1945; Hansen and others 1990).

The environmental conditions in which seedlings are grown usually have the greatest influence on the development of damping-off. However, the specific conditions that promote damping-off depend on the pathogens present.

Pythium. Pythium damping-off increases under high soil moisture (Wright 1957) and pH (greater than 5.8) (Roth and Riker 1943b, 1943c). The effect of temperature on *Pythium is* variable and depends on the growth rates of the host and fungus. Preemergence infection is greater when temperatures are more favorable for the fungus than for the host (Roth and Riker 1943b, Leach 1947). For example, high soil moisture combined with warm (18 to 30 °C, 64 to 86 °F) temperatures can favor damping-off by *Pythium.* However, preemergence damping-off by *Pythium* can also be very damaging at low temperatures (12 °C, 54 °F) when combined with high moisture and the absence of competitive microbes. *This Pythium* damping-off corresponds to the slow growth and emergence of the host at low temperatures (Roth and Riker 1943b).

Rhizoctonia. The conditions that promote *Rhizoctonia* damping-off differ from those that favor *Pythium* damping-off. *Rhizoctonia* damping-off losses increase with increasing soil temperatures and increasing dryness (Wright 1957) and decrease with excessive moisture (Roth and Riker 1943b). *Rhizoctonia is* less affected by pH than *Pythium* (Jackson 1940), and the activity of *Rhizoctonia* in the soil is greatly stimulated by nitrogen. In soils with high carbon-to-nitrogen ratios, the activity of *Rhizoctonia* decreases (Papavizas and Davey 1961).

Fusarium. Fusarium damping-off increases with increasing soil pH and with increased nitrogen (Tint 1945). The effects of temperature on damping-off by *Fusarium* are mixed and depend on the virulence of the fungus. Huang and Kuhlman (1990) found that highly pathogenic isolates of *F. subglutinans* Wollenw. & Reink. were less responsive to high temperature than less virulent species that significantly increased damping-off at high (30 °C, 86 °F) temperatures.

Phytophthora. In general, *Phytophthora* diseases are promoted by water-saturated soils (Duniway 1983) and increasing pH up to 8.0 (Schmitthenner and Canaday 1983). Lambert (1936) found that acidifying soil to a pH of 4.6 controlled damping-off of black locust *(Robinia pseudoacacia L.) by P. parasitica* Dast. The effects of temperature and nitrogen on *Phytophthora* diseases are variable for other crops and have not been well documented for damping-off of forest tree species in the United States.

Beneficial microorganisms. Environmental conditions can affect populations of beneficial microorganisms, as well as pathogens. For example, *Trichoderma harzianum* Rifai populations are greater in acidic soil conditions and suppress *Rhizoctonia solani* Kiihn at a soil pH of 4.3 (Huang and Kuhlman 1991). A reduction in damping-off of pine *(Pin us spp.)* seedlings by competing microorganisms also occurs with *Pythium spp.* (Hartley 1921; Roth and Riker 1943b), *Fusarium spp.* (Chakravarty and others 1990; Pedersen and others 1999), and *Cylindrocladium scoparium* Morg. (Yang and others 1995).

Management

Nursery managers can reduce damping-off by promoting fast germination and good seedling growth (Filer and Peterson 1975). Managers have a great deal of control over the factors that affect damping-off in the field, outside of the weather. Soil drainage, organic mat ter, and pH can be influenced. The timing and depth of sowing and irrigation can be controlled to improve germination. Nitrogen application can be delayed until seedlings are past the danger of damping-off. If necessary, fumigants and fungicides are available to control disease development.

Soil condition. Manipulation of the soil condition in the nursery beds can greatly affect damping-off. Soil drainage can be improved by subsoiling, crowning the beds, installing drainage tiles, and adding composted organic matter, such as composted pine bark. Organic matter affects soil texture, water-holding capacity, nutrient availability, cation exchange capacity, soil pH, and the presence and function of microorganisms. These changes are usually positive for seedling growth and survival when the origin and quality of the organic amendments are known. However, managers need to watch for N and Fe deficiencies and increases in soil pH that can occur with the addition of some organic amendments (Davey 1996). The pH of the soil can be returned to optimum (pH 5.2 to 5.7) with applications of aluminum sulfate, sulfur, or acid peat (Russell 1990). Although alkaline irrigation water can also increase soil pH over time, the water can be acidified by the addition of sulfuric or phosphoric acid if necessary (Russell 1990).

Cover crops. Cover crops are used to produce some organic matter and protect the soil from erosion and leaching (Davey 1996). They are also used as an alternate crop for disease control, but this benefit can vary with the species of cover crop. Legume cover crops often favor greater populations of damping-off fungi than grass crops (Hansen and others 1990; Russell 1990). This difference can sometimes be maintained even after fumigation (Hansen and others 1990). Fallow fields have lower populations of damping-off fungi than fields in cover crops (Russell 1990) and are comparable to fumigated fields that had been in cover crops (Hansen and others 1990).

Sowing. Usually seeds are sown when conditions are most favorable for fast and even germination. However, managers may be forced to sow seeds in an unusually warm or wet spring. This may favor fast germination but will require greater attention to watering. To avoid damping-off, soils should be irrigated to the depth of the growing roots without flooding the soil.

Fumigants. In a 1993 national survey of forest nursery managers, routine soil fumigation was used to control soil-borne disease, insects, and weeds by 86% of nurseries that produced bareroot tree seedlings (Smith and Fraedrich 1993). Fumigants that reduce the soilborne pathogens associated with damping-off include methyl bromide with chloropicrin, metam sodium (Vaartaja 1964), 100% chloropicrin, dazomet (Hansen and others 1990), and 1,3-dichloropropene (Csinos and others 2000).

Fungicides. Fungicides are used in many forest nurseries in an attempt to prevent damping-off. However, results are erratic (James 1988; Kelley and Oak 1989; Russell 1990). In general, fungicides are most effective when targeted at a specific pathogen and applied prior to disease development. Since predicting damping-off is difficult (Wright 1945), managers often rely on experience with the pathogens and conditions that cause damping-off and the fungicides, if any, that provided some control. To determine if a fungicide in use is providing control of damping-off, a few untreated plots can be established in the beds or containers. This test may have to be repeated for several years to get an accurate assessment of a fungicide. When a new chemical is to be used, it can be tested in a small area before it is applied to the entire crop.

A number of fungicides currently in use by nurseries are very specific concerning the damping-off pathogens they control. Preplant application of metalaxyl, fosetylaluminum, or etridiazole can be used to prevent damping-off by *Pythium* and *Phytophthora.* Drench applications of thiophanate-methyl may reduce damping-off by *Fusarium, Rhizoctonia, Botrytis,* and *Cylindrocladium.* Iprodione is a preplant drench for control of *Rhizoctonia* and a foliar spray for control of *Botrytis.* Broad-spectrum fungicides used to prevent damping-off include captan and a fungicide containing 15% etridiazole and 25% thiophanate-methyl. Fungicides with different modes of action should be alternated to prevent the development of resistant pathogens (Vaartaja 1964; James 1988; Russell 1990).

Seed treatments to control damping-off also provide variable results (Vaartaja 1964). Fungicides and sterilants can reduce pathogenic fungi on the seedcoat and improve germination. However, these same treatments can have phytotoxic effects depending on the species of seed, condition of the seedcoat, and application method (Vaartaja 1964; Runion and others 1991). Cleansing seed surfaces with a running water soak for 48 h is a nontoxic treatment that relies on mechanical removal of pathogens (Campbell and Landis 1990). This treatment can be used in combination with sterilants as a rinse.

Thiram is the most commonly applied seed treatment for use as a bird and small mammal repellant, as well as a fungicide for specific damping-off pathogens, such as *Fusarium* (Littke 1997), *Pythium,* and *Rhizoctonia* (Vaartaja 1964). However, thiram may delay or reduce germination of seeds of some tree species including red pine (Belcher and Carlson 1968), white spruce (Dobbs 1971), longleaf pine, and slash pine (Runion and others

1991). Few studies have determined whether the benefit of thiram as an animal repellent and fungicide exceeds its possible phytotoxic effect in the field.

Seed treatments with sodium hypochlorite (bleach) and hydrogen peroxide can reduce pathogenic fungi on the seedcoat and improve seed germination (Campbell and Landis *1990;* Barnett and Pesacreta *1993).* But these seed treatments can also reduce seed germination depending on the tree species, concentration, and duration of application (Campbell and Landis *1990;* Barnett and Pesacreta *1993).* Hydrogen dioxide *is* a surface sterilant registered as a fungicide for tree seed; however, there are no independent studies published on the efficacy of this chemical on forest tree seeds.

Summary

Damping-off is a common disease problem in forest nurseries during the 1st *4* to 6 wk after sowing. The primary fungi involved in damping-off are *Pythium, Rhizoctonia, Fusarium,* and *Phytophthora* species. Many damping-off fungi are relatively weak pathogens that require environmental conditions that favor infection. The severity of damping-off is highly dependent on whether the *soil* moisture, temperature, and pH are more beneficial to the growth of the host or the pathogen. Other factors that can affect development of the disease, aside from host susceptibility and pathogen populations, include the level of available nitrogen, presence of antagonistic microorganisms, and variation in pathogenicity within a fungal species. Managers can reduce the risk of damping-off by promoting environmental conditions for fast germination and good seedling growth. Fumigants and fungicides can also be used to reduce populations of pathogens and prevent seedling infection. Pesticides can be phytotoxic and should be used with caution.

Address correspondence **to:** Michelle Cram, USDA Forest Service, *320* Green St., Athens, GA *30602-2044;* **email:** < mcram@fs.fed.us >.

Acknowledgments

I would like to thank Dr.'s Robert James and Stephen Fraedrich for editing this article.

References

Barnett JP, Pesacreta TC. 1993. Handling longleaf pine seeds for optimal nursery performance. Southern Journal of Applied Forestry 17(4):180-186.

Belcher J, Carlson LW. 1968. Seed-treatment fungicides for control of conifer damping-off: laboratory and greenhouse tests, 1967. Canadian Plant Disease Survey 48(2): 87-52.

Boyce JS. 1961. Forest pathology. 3rd ed. New York: McGrawHill. 572 p.

Campbell SJ, Landis TD. 1990. Managing seedbome diseases in western forest nurseries. Tree Planters' Notes 41(4): 3-7.

Chakravarty P, Peterson RL, Ellis BE. 1990. Integrated control of *Fusarium* damping-off in red pine seedlings with the ectomvcorrhizal fungus *Paxillus involutus* and fungicides. Canadian Journal of Forest Research 20: 1283-1288.

Cram MM, Fraedrich SW. 1996. Survey of southern forest nurseries: fumigation practices and pest management concerns. In: Landis TD, South DB, editors. National Proceedings, Forest and Conservation Nursery Associations. Portland (OR): USDA Forest Service, Pacific Northwest Research Station. General Technical Report PNW-389. p 19-27.

Csinos AS, Sumner DR, Johnson WC, Johnson AW, McPherson RM, Dowler CC. 2000. Methyl bromide alternatives in tobacco, tomato, and pepper transplant production. Crop Protection 19: 39-49.

Davey CB. 1996. Nursery soil management-organic amendments. In: Landis TD, South DB, editors. National Proceedings, Forest and Conservation Nursery Associations. Portland (OR): USDA Forest Service, Pacific Northwest Research Station. General Technical Report I'NW-389. p 6-18.

Dobbs RC. 1971. Effect of thiram-endrin formulations on the germination of jack pine and white spruce seed in the laboratory. Tree Planters' Notes 22: 16-18.

Duniway JM. 1983. Role of physical factors in the development of *Phytophthora* diseases. In: Erwin DC, Bartnicki-Garcia S, Tsao PH, editors. *Phytophthora:* its biology, taxonomy, ecology, and pathology. St. Paul (MN): American Phytopathological Society. p 175-187.

Filer TH Jr, Peterson GW. 1975. Damping-off. In: Peterson GW, Smith RS, technical coordinators. Forest nursery diseases in the United States. Washington (DC): USDA Forest Service. Agriculture Handbook No. 470. p 6-8.

Fisher PL. 1941. Germination reduction and radicle decay of conifers caused by certain fungi. Journal of Agricultural Research 62: 87-95.

Hansen EM, Myrold DD, Hamm PB. 1990. Effects of soil fumigation and cover crops on potential pathogens, microbial activity, nitrogen availability, and seedling quality in conifer nurseries. Phytopathology 80: 698-704.

Hartley C. 1918. Stem lesions caused by excessive heat. Journal of Agricultural Research 14: 595-604.

Hartley C. 1921. Damping-off in forest nurseries. Washington (DC): USDA Bureau of Plant Industry. Bulletin 934. 99 p.

Huang JW, Kuhlman EG. 1990. Fungi associated with damping-off of slash pine seedlings in Georgia. Plant Disease 74: 27-30.

Huang JW, Kuhlman EG. 1991. Mechanisms inhibiting damping-off pathogens of slash pine seedlings with a formulated soil amendment. Phytopathology 81: 171-177.

Jackson LW. 1940. Effects of H-ion and Al-ion concentrations on damping-off of conifers and certain causative fungi. Phytopathology 30: 563-579.

James RL. 1988. Principles of fungicide usage in container tree seedling nurseries. Tree Planters' Notes 39: 22-25.

Kelley WD, Oak SW. 1989. Damping-off. In: Cordell CE, Anderson RL, Hoffard WH, Landis TD, Smith RS Jr, Toko HV, editors. Forest nursery pests. Washington (DC): USDA Forest Service. Agriculture Handbook No.

680. p 118-119.

Lambert EB. 1936. A seedling wilt of black locust caused by *Phytophthora parasitica.* Journal of Agricultural Research 53: 467-476.

Leach LD. 1947. Growth rates of host and pathogen as factors determining the severity of preemergence damping-off. Journal of Agricultural Research 75: 161-179.

Littke W. 1997. Seed pathogens and seed treatments. In: Landis TD, South DB, editors. National Proceedings, Forest and Conservation Nursery Associations. Portland (OR): USDA Forest Service, Pacific Northwest Research Station. General Technical Report PNW-389. p 187-191.

Papavizas CG, Davey CB. 1961. Saprophytic behavior of *Rhizoctonia* in soil. Phytopathology 51: 693-699.

Pedersen EA, Reddy MS, Chakravarty P. 1999. Effect of three species of bacteria on damping-off, root rot development, and ectomycorrhizal colonization of lodgepole pine and white spruce seedlings. European Journal of Forest Pathology 29: 123-134.

Roth LF, Riker AJ. 1943a. Life history and distribution of *Pythium* and *Rhizoctonia* in relation to damping-off of red pine seedlings. Journal of Agricultural Research 67:129-148.

Roth LF, Riker AJ. 1943b. Influence of temperature, moisture, and soil reaction on the damping-off of red pine seedlings *by Pythium* and *Rhizoctonia.* Journal of Agricultural Research 67: 273-293.

Roth LF, Riker AJ. 1943c. Seasonal development in the nursery of damping-off of red pine seedlings caused by *Pythium* and *Rhizoctonia.* Journal of Agricultural Research *67:* 417431.

Runion GB, Kelley WD, Land DH. 1991. Effects of triadimefon and thiram seed treatments on emergence of southern pines. Seed Science & Technology 19: 57-66.

Russell K. 1990. Damping-off. In: Hamm PB, Campbell SJ, Hansen EM, editors. Growing healthy seedlings: identification and management of pests in Northwest forest nurseries. Corvallis (OR): Forest Research Laboratory, Oregon State University. Special publication 19. p 2-5.

Schmitthenner AF, Canaday CH. 1983. Role of chemical factors in development of *Phytophthora* diseases. In: Erwin DC, Bartnicki-Garcia S, Tsao PH, editors. *Phytoplithora:* its biology, taxonomy, ecology, and pathology. St. Paul (MN): American Phytopathological Society. p 175-187.

Smith RS, Fraedrich SW. 1993. Back to the future-pest management without methyl bromide. Tree Planters' Notes 44 (3):87-90.

Sutherland JR. 1984. Pest management in northwest bareroot nurseries. In: Duryea ML, Landis TD, editors. Forest nursery manual: Production of bareroot seedlings. The Hague (The Netherlands): Martinus Nijhoff, Dr W Junk, Publishers, for Forest Research Laboratory, Oregon State University, Corvallis. p 203-210.

Tint H. 1945. Studies in the *Fusarium* damping-off of conifers. II. Relation of age of host, pH, and some nutritional factors to the pathogenicity of *Fusarium.* Phytopathology 35: 440457.

Vaartaja O. 1964. Chemical treatment of seedbeds to control nursery diseases. Botanical Review 30(1): 1-91.

Vaartaja O. 1967. Reinfestation of sterilized nursery seedbeds by fungi. Canadian Journal of Microbiology 13: 771-776.

Wright E. 1944. Damping-off in broadleaf nurseries of the Great Plains Region. Journal of Agricultural Research 69: 77-94.

Wright E. 1945. Relation of macrofungi and micro-organisms of soil to damping-off of broadleaf seedlings. Journal Agricultural Research 70: 133-141.

Wright E. 1957. Influence of temperature and moisture on damping-off of American and Siberian elm, black locust, and desertwillow. Phytopathology 47:658-662.

Yang D, Bernier L, Dessureault M. 1995. *Phaeotheca dimorphospora* increases *Trichoderma harzianurn* density in soil and suppresses red pine damping-off caused *by Cylindrocladium scoparium.* Canadian Journal of Botany 73: 693-700.