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RHABDOCLINE NEEDLE CAST AT THE BIGFORK TREE IMPROVEMENT SITE, FLATHEAD NATIONAL FOREST, MONTANA

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The Bigfork Tree Improvement Site was established in 1985 to test genetic growth potential of seedlings obtained from seed of superior wild trees. One of the major species to be assessed at the site is Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). Prior to establishing plantations of this species, managers were aware of the potential impact of an important needle disease possibly caused by two species of *Rhabdocline* (*R. pseudotsugae* Syd. and *R. weirii* Parker & Reid). This disease has a history of extensive impact on Christmas tree plantations in and around the Bigfork area. Damage has been so extensive that many growers have replaced Douglas-fir with other species such as Scotch pine which are not susceptible to *Rhabdocline*.

Shortly after the tree improvement site was developed, an early selection trial of Douglas-fir was established in the northeast corner of the site. The plantation was periodically evaluated for growth performance. Managers controlled competing vegetation and established schedules of fungicide applications to prevent infection by *Rhabdocline*. Chlorothalonil (Bravo®) was applied during the spring when conducive conditions for infection by *Rhabdocline* prevailed. This strategy focused on prevention of buildup of the pathogen in the plantation rather than therapeutic treatment of trees with fungicides once the disease was encountered.

Yearly examinations of the plantation failed to reveal high levels of *Rhabdocline* until the spring of 1991 (James 1989). During the 1991 examination, many trees displayed extensive levels of disease (figure 1). Diseased needles were concentrated within lower portions of crowns (figure 2); many needles nearest the main stem were absent, indicating they had been infected during previous years and were prematurely lost.

In the west central portion of the site, another plantation of Douglas-fir has been growing for four years. This plantation had limited indications of *Rhabdocline* during 1991 with damage much less than in the older plantation.

On diseased trees, the upper surface (epiphyllous) of needles displayed distinct bands of necrosis interspersed with zones of green, healthy tissue (figure 3). On the undersurface (hypophyllous) of needles, elongate fruiting bodies (apothecia) of *Rhabdocline* developed on either side of the midrib, parallel with rows of stomata (figure 4). Apothecia develop subcuticularly from fungal stroma within infected needle tissues (Parker and Reid 1969). When mature, the apothecia rupture host epidermal tissues, exposing layers of spores (hymenium) underneath (Parker and Reid 1969; Skilling and Morton 1983)(figure 4). During periods of rainfall or irrigation when apothecia become wet (figure 5), structures containing spores (asci) imbibe water, swell, and their spores (ascospores) are forcibly ejected (Parker 1970; Parker and Reid 1969). Spores are either rain-splashed or wind disseminated onto surfaces of young emerging Douglas-fir needles which become infected (Parker 1970).

For successful infection, *Rhabdocline* spores require periods of at least 72 hrs of continuous 100% relative humidity (Parker 1970). During this period, spores germinate on and germ tubes grow over needle surfaces,

and fungal penetration into host epidermal cells occurs (Parker 1970; Parker and Reid 1969). If needle surfaces dry out before the fungus penetrates into epidermal cells, infection cannot occur.

Douglas-fir needles in the process of elongating from recently broken buds in the spring are the most susceptible to infection (Morton and Miller 1982; Stambaugh and Bramble 1952). *Rhabdocline* apothecia maturity and spore release corresponds to presence of young susceptible needles from new flushes of growth in the spring (Parker and Reid 1969; Weir 1917). In many areas, these developmental process also correspond to ideal weather conditions for spore release and needle infection, i. e., prolonged periods of cool, wet weather (Parker 1970).

Figure 1. Rhabdocline needle cast on last year's needles of Douglas-fir at the Bigfork Tree Improvement Site.

Once *Rhabdocline* becomes established in plantations, with accompanying high levels of inoculum, damage often increases until trees become large enough that they are not as susceptible (O'Brien and Morton 1983). When trees produce abundant foliage close to the ground, disease damage is usually localized in the lower foliage (Sinclair and Dwinell 1986)(figure 2). However, as trees grow in stands, less foliage is produced near the ground and disease damage is usually less. Apparently, the high humidity conditions necessary for infection are more common near the ground (Day 1927).

Taxonomists have identified at least two species of *Rhabdocline* that cause needle cast of Douglas-fir. Descriptions and keys to the taxa are presented in the Appendix. Examination of infected needles from the Bigfork site revealed presence of predominately *R. pseudotsugae*, based on predominant medial dehiscence of epidermal coverings at maturity (figure 4)(Parker and Reid 1969). Means of epidermal dehiscence at

ascocarp maturity has been useful as a cursory means of differentiating *Rhabdocline* speciation (O'Brien and Morton 1983; Parker and Reid 1969), although this character may not always be reliable (Harringon 1986). The most accurate diagnostic tool is production of a blue reaction by asci when exposed to Melzer's reagent (Parker and Reid 1969). *Rhabdocline pseudotsugae* has previously been described in Montana (Weistaner 1955). Both *Rhabdocline* species causing needle cast of Douglas-fir have been previously reported in the western United States (Parker and Reid 1969). Another recently described species of *Rhabdocline*, *R. parkeri* Sherwood-Pike, Stone & Carroll is often associated with Douglas-fir foliage, but is a non-disease causing endophyte, which becomes active only during natural needle senescence (Sherwood-Pike and others 1986).

Figure 2. Rhabdocline needle cast concentrated at the base of plantation trees at the Bigfork Tree Improvement Site.

Previous experience with this disease (Meyer 1951; Skilling and Morton 1983) indicates that fungicides must be applied at least three times in the spring during shoot elongation in order to adequately protect new needles from infection. Three-week intervals between fungicide applications are usually recommended (Brandt 1960; Morton and Miller 1982), but this should be adjusted to compensate for precipitation that commonly occurs in the spring. Both chlorothalonil and benomyl have been recommended to control this disease (Morton and Miller 1982; Skilling and Morton 1983).

The older plantation at the Bigfork site is scheduled for a final growth evaluation at the end of the 1991 growing season. It will then be converted to a seed orchard with many individual trees removed. *Rhabdocline* is expected to continue to cause disease of older trees and control efforts will probably be required in seed orchard trees.

Differences in susceptibility to *Rhabdocline* among Douglas-fir genotypes are usually evident (Hoff 1987; Stephan 1973). Rocky Mountain genotypes (var. *glauca*) are considered more susceptible to the disease than Pacific coast genotypes (var. *menziesii*)(Hepting 1971). Families with the highest resistance were from the low elevation zone, whereas mid and high elevation families displayed about the same level of resistance (Hoff 1987). There may be relationships between disease resistance and growth potential of Douglas-fir (Kurkela 1981), particularly if trees are destined for areas of high disease incidence. Because of the relatively widespread nature of infection evident in 1991, differences in amount of foliage discoloration due to the disease are probably due to genetic differences in susceptibility. Scoring trees for extent of foliage discoloration and casting of lower needles may be important in assessing genetic differences in susceptibility. This information would be useful in selecting individuals destined to become seed orchard trees. Improving resistance to *Rhabdocline* in populations of Douglas-fir is possible; such a goal may be as important as other selection criteria (Hoff 1987).

Continued vigilance to provide fungicide protection to Douglas-fir at the Bigfork Tree Improvement Site will be necessary. *Rhabdocline* will likely continue to be a problem, and disease intensity may increase because of increasing amounts of inoculum present in plantations. After the first few years when trees get older, they apparently become more damaged by the disease. Very young plantations suffer little from *Rhabdocline*, but after 4-5 years, disease severity increases. Increased disease may occur even with fungicide applications, particularly if conducive weather occurs during periods of infection and inoculum builds up in plantations. Fungicides should ameliorate disease levels, but may not consistently keep disease intensity low.

Unfortunately, growing Douglas-fir at the Bigfork Tree Improvement Site will require continued efforts to control Rhabdocline needle cast. Much is known about the disease and the pathogens responsible for it as well as practical approaches to control. Two approaches to dealing with the disease are recommended: (1). fungicide applications at two-to-three week intervals commencing at bud break and continuing until warm weather prevails and (2). scoring trees within plantations for relative susceptibility to the pathogens in order to select those genotypes displaying the highest level of resistance. These approaches should help managers deal with problems from this disease in the future.

Figure 3. Necrotic banding on epiphyllous surface of Douglas-fir needles infected with *Rhabdocline* at the Bigfork Tree Improvement Site.

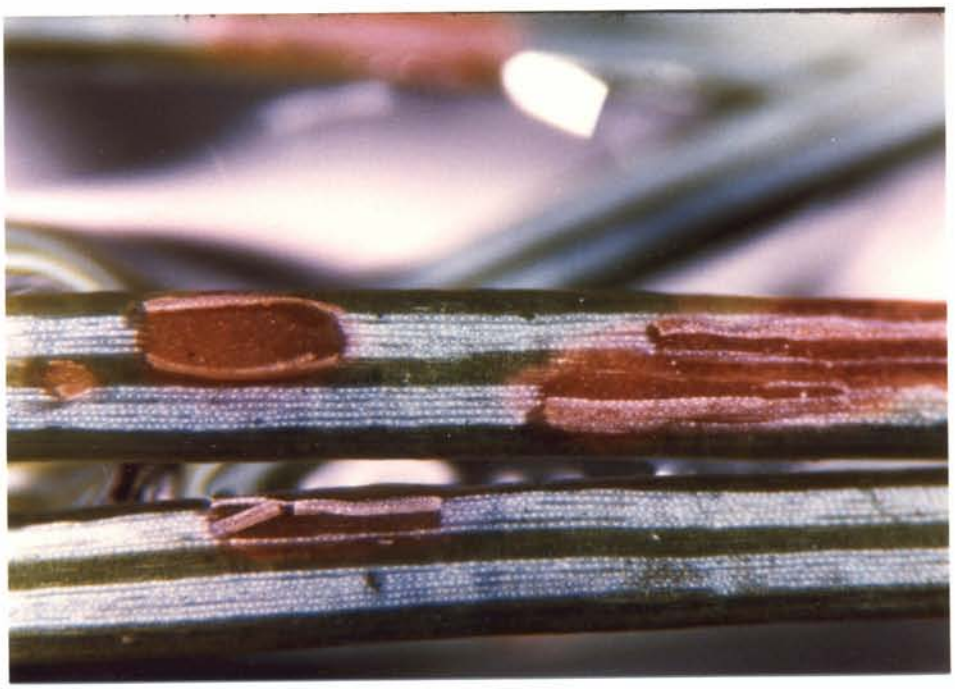

Figure 4. Mature apothecia of *Rhabdocline* produced on hypothallous surface of Douglas-fir needles from the Bigfork Tree Improvement Site.

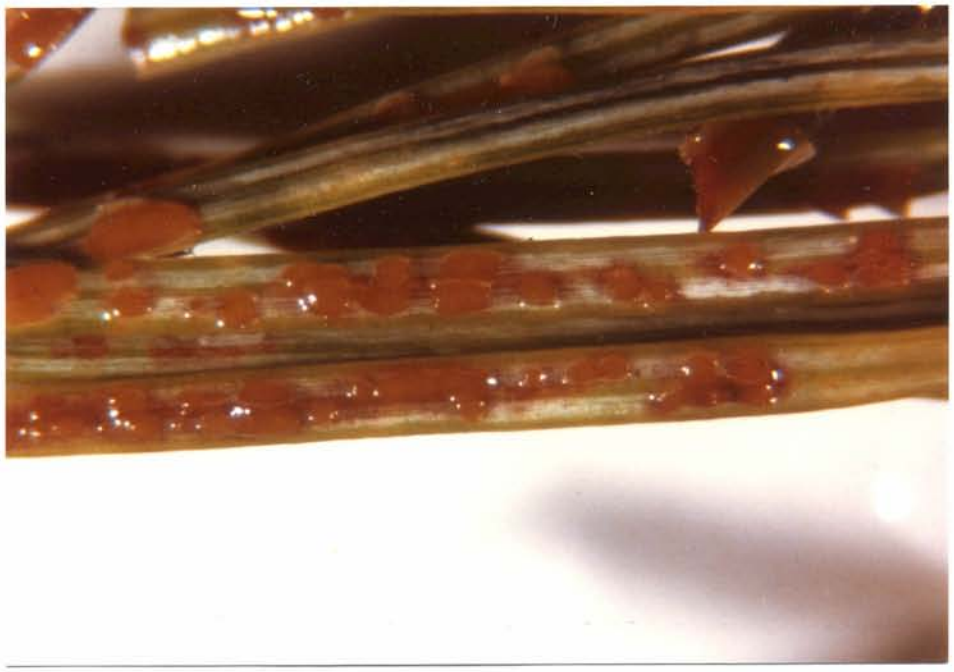

Figure 5. Mature apothecia on Douglas-fir needles which have become wet. Asci imbibe water, swell, and release their ascospores which cause infection of young Douglas-fir needles.

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APPENDIX

Key to the Species and Subspecies of the Genus *Rhabdocline* (see Parker and Reid (1969) and Sherwood-Pike and others (1986):

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1. Not causing needlecast of Douglas-fir, but confined as an endophyte on green needles and an active colonizer of senescent needles...*R. parkeri*

2. Causing needlecast disease of Douglas-fir

   A. Ascus apices lacking a pore structure (not blueing in Melzer's reagent)

      1. Apothecia hypophyllous rarely epiphyllous; paraphyses filamentous, to slightly swollen at their tips..... .*R. pseudotsugae* subsp. *pseudotsugae*.
      2. Apothecia epiphyllous; paraphyses with large, swollen clavate tips .....*R. pseudotsugae* subsp. *epiphylla*

   B. Ascus apices with a well-developed pore structure (turns blue in Melzer's reagent)

      1. Ascospores oblong with obtuse ends, to slightly constricted at the middle; apothecia hypophyllous, on 1-year-old and older needles

         a) Apothecia varying in size and shape from small flecks less than 1 mm in diameter to those 5-10 mm in length and occupying half the width of the needle; on l-year-old and older needles; associated with *Rhabdogloeum pseudotsugae* .....*R. weirii* subsp. *weirii*
         b) Apothecia usually rectangular in outline and occupying the full width of the needle; chiefly on 1-year-old needles ....*R. weirii* subsp. *oblonga*

      2. Ascospores obovate with obtuse ends, 1 or 2-celled; apothecia hypophyllous, on 2-year-old and older needles .....*R. weirii* subsp. *obovata*

Species Descriptions:

Rhabdocline parkeri Sherwood-Pike, Stone, & Carroll

Apothecia hypophyllous, immersed in the stomatal area, at maturity becoming exposed by lifting a minute patch of overlying epidermis, circular to slightly elongate, 0.05-0.5 mm in diameter, dull orange. Stroma and excipular tissue absent. Hypothecium hyaline, of small-celled pseudoparenchyma. Paraphyses numerous, septate, with their apical cell inflated. Asci cylindric-clavate, subsessile, thin-walled at all stages of development with a prominent apical ring (blue in Melzer's reagent), produces 8 ascospores. Ascospores oblong, sometimes slightly constricted in the middle, without a gelatinous sheath but with evanescent gelatinous polar appendages, becoming 1-septate upon germination, with one hyaline cell and one smooth brown cell. Anamorph: *Meria parkeri*

Rhabdocline pseudotsugae Syd.

Apothecia mostly hypophyllous, rarely epiphyllous, on one or both sides of the needle midrib; subepidermal, becoming erumpent by the median splitting of the overlying epidermis; in smaller apothecia the epidermis ruptures occasionally in a lateral manner with the epidermis remaining attached as a lateral flap of tissue. Apothecia usually situated in small necrotic spots which are irregularly circular in outline; larger necrotic areas frequently contain several confluent apothecia or a number of discrete apothecia arranged linearly; 0.5-10 mm in length and 0.3-0.6 mm wide. Apothecia very simple, essentially only a layer of asci and paraphyses borne on a poorly developed hypothecium. Asci clavate, broadest below the apex and tapering abruptly above to a flattened or broadly rounded tip; pore structure lacking (not blueing in Melzer's reagent); 8-spored. Ascospores hyaline, 1- or 2-celled, oblong to slightly constricted at the middle with obtuse ends; with a thick, gelatinous sheath; one cell turns dark brown with a finely pitted wall and increases slightly in size; the other cell remains hyaline or becomes very pale brown. Paraphyses septate, occasionally slightly swollen and clavate at their tips.

Rhabdocline weirii Parker & Reid

Apothecia hypophyllous, on one or both sides of the needle midrib; subepidermal, becoming erumpent chiefly by the lateral to occasionally irregular splitting of the overlying epidermis; situated on necrotic bands of host tissue of varying lengths occasionally extending across the entire width of the needle; varying in size and shape from small circular to irregular flecks less than 1mm in diameter to those rectangular in outline, 5-10 mm long and up to 0.5 mm wide and then occupying one-half the width of the needle. Apothecia simple, composed of a layer of asci and paraphyses produced on a poorly developed hypothecium. Asci clavate, broadest below the apex and tapering abruptly above to a flattened tip; occasionally curving slightly toward the apex; with distinct apical pore (turning blue in Melzer's reagent); 8-spored. Ascospores hyaline 1- or 2-celled, oblong with obtuse ends to more frequently oblong and constricted at the middle, with a thick gelatinous sheath; one cell turning dark brown, with or without a finely pitted wall and increasing somewhat in size; the other cell remaining hyaline or becoming slightly pale brown. Paraphyses filiform, septate, occasionally slightly swollen and clavate at their tips.