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REGIONAL COPPER-NICKEL STUDY

PLANT DISEASES AFFECTING FOREST TREES IN NORTHEASTERN MINNESOTA'S REGIONAL COPPER-NICKEL STUDY AREA

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PRELIMINARY DRAFT REPORT, SUBJECT TO REVIEW

INTRODUCTION

This report is based upon lists of major vegetation community types, compiled for a preliminary study of the Regional Copper-Nickel Study Area. Only dominant plant species, as determined by relevé techniques, have been included in the discussion of diseases.

The intent of this report is to present a brief survey of the major diseases caused primarily by biotic agents. The information was obtained from general references and from personal observations of the diseases of the area over the past 11 years. The report is divided into two parts: (1) a comprehensive table of diseases recorded in the area and their causal agents (Table 1), and (2) brief descriptions of 25 diseases of exceptional economic or aesthetic importance. In some cases, particularly for less well documented aesthetically important (conspicuous) but not economically important diseases, no description is included. No attempt was made to deal with the extreme complexity of disease organism interactions and ecology or to update fungal nomenclature and taxonomy. The approach was to use concepts and nomenclature employed in most of the standard reference sources.

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Table 1. Plant diseases and their causal agents that affect forest tree species in northeastern Minnesota. Host species based on plant lists for major vegetation community types produced during the Regional Copper-Nickel Study.

DISEASES OF CONIFERS

Tree species (Hosts)	Disease or Symptom	Causal Agent	Importance 1/
A. Balsam fir (*Abies balsamea*)	Butt rot	*Corticium galactinum*	a
		Polyporus balsameus	a
	Canker	*Cephalosporium album*	
		Dasyscyphus resinarius	
		Thyronectria balsamea	
	Rusts, witches broom	*Melampsorella caryophyllacerarum*	b
	fir-needle	*Melampsora abieti-capraearum*	
	fir-fern	*Uredinopsis mirabilis*	
	Trunk rot	*Fomes officinalis*	
		Fomes pini	
		Stereum sanguinolentum	
	Twig and bark canker	*Cytospora pinastri*	
	Shoestring root rot	*Armillaria mellea*	a,b

1/ a = Economically important, potentially serious disease

b = Aesthetically important, conspicuous symptoms

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Table 1 (continued)

Tree species (Hosts)	Disease or Symptom	Causal Agent	Importance
B. Tamarack (*Larix laricina*)	Butt rot	*Polyporus schweinitzii*	
	Dwarf misteletoe	*Arceuthobium pusillum*	
	Canker	*Aleurodiscus amorphus*	
	Needle cast	*Hypodermella laricis*	
	Needle rust	*Melampsora bigelowii*	
C. White spruce (*Picea glauca*)	Butt rot	*Polyporus schweinitzii*	
	Dwarf mistletoe	*Arceuthobium pusillum*	
	Rusts, cone	*Chrysomyxa pirolata*	
	needle	*Chrysomyxa* spp. (two species)	b
	witches broom	*Melampsorella caryophyllacearum*	
	Trunk rot	*Fomes pini*	
		Fomes pinicola	
		Polyporus tomentosus	b
		Stereum sanguinolentum	
	Shoestring root rot	*Armillaria mellea*	
D. Black spruce (*Picea mariana*)	Butt rot	*Polyporus schweinitzii*	
	Dwarf mistletoe	*Arceuthobium pusillum*	a,b
	Rusts, cone	*Chrysomyxa pirolata*	
	needle	*Chrysomyxa* spp. (three species)	b

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Table 1 (continued)

Tree species (Hosts)	Disease or Symptom	Causal Agent	Importance
D. Black spruce (continued)	Trunk rot	Stereum sanguinolentum	a
		Corticium galactinum	a
		Fomes pini	a
	Shoestring root rot	Armillaria mellea	
E. Jack Pine (Pinus banksiana)	Butt rot	Polyporus schweinitzii	
		Polyporus tomentosus	
	Needle cast	Davisomycella ampla	
		Lophodermium spp.	
	Rusts, blister	Cronartium comandrae	
		Cronartium comptoniae	
	Eastern gall	Cronartium quercuum	a,b
	Western gall	Peridermium harknessii	
	needle	Coleosporium spp. (four species)	
	stem	Peridermium stalactiforme	
	Trunk rot	Fomes pini	
		Fomes pinicola	
	Shoestring root rot	Armillaria mellea	

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Table 1 (continued)

Tree species (Hosts)	Disease or Symptom	Causal Agent	Importance
F. Red Pine (*Pinus resinosa*)	Butt rot	*Polyporus schweinitzii* *Polyporus tomentosus*	
	Branch canker	*Scleroderris lagerbergii*	a
	Needle cast	*Lophodermium pinastri*	
	Needle rust	*Coleosporium* spp. (two species)	
	Trunk rot	*Fomes pini* *Fomes pinicola*	
	Shoestring root rot	*Armillaria mellea*	
G. White Pine (*Pinus strobus*)	Blister rust	*Cornartium ribicola*	a,b
	Butt rot	*Polyporus schweinitzii* *Polyporus tomentosus*	
	Needle cast	*Bifusella linearis*	
	Shoestring root rot	*Armillaria mellea*	
	Trunk rot	*Fomes pini* *Fomes pinicola* *Lentinus lepideus* *Stereum sanguinolentum*	
H. Northern White Cedar (*Thuja occidentalis*)	Butt rot	*Polyporus schweinitzii*	
	Leaf blight	*Didymascella thujina*	
	Leaf spot	*Lophodermium thuyae*	

Table 1 (continued)

Tree species (Hosts)	Disease or Symptom	Causal Agent	Importance
H. Northern White Cedar (continued)	Trunk rot	Fomes pini Fomes pinicola Polyporus balsameus	

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Table 1 (continued)

DISEASES OF BROADLEAFED SPECIES

Tree species (Hosts)	Disease or Symptom	Causal Agent	Importance
A. Red Maple (*Acer rubrum*)	Anthracnose	*Gloeosporium apocryptum*	
	Canker	*Nectria galligena*	a
		Hypoxylon mammatum	
	Leaf spot	*Phyllosticta minima*	
		Septoria aricis	
	Black leaf blister	*Taphrina dearnessii*	
	Tar spot	*Rhytisma acerinum*	
	Shoestring root rot	*Armillaria mellea*	
	Trunk canker	*Eutypella parasitica*	a
	Trunk rot	*Fomes igniarius*	a
		Fomes connatus	
		Polporus glomeratus	a
B. Paper Birch (*Betula papyrifera*)	Canker	*Cytospora spp.* (two species)	
		Nectria galligena	b
	Charcoal canker	*Poria obligua*	b
	Dieback	(abiotic, soil temp.)	a,b
	Leaf blister	*Taphrina flava*	
	Rust	*Melampsoridium betulinum*	
	Shoestring root rot	*Armillaria mellea*	a

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Table 1 (continued)

Tree species (Hosts)	Disease or Symptom	Causal Agent	Importance
B. Paper Birch (continued)	Trunk rot	Fomes fomentarius	b
		Fomes ignarius	
	Witches' broom	Taphrina americana	
C. Black Ash (Fraxinus nigra)	Leafspot	Cylindrosporium fraxini	
		Gloeosporium aridum	
	Trunk rot	Fomes fraxinophilus	b
	Rust	Puccinia peridermiospora	
	Powder mildew	Phyllactinia corylea	
D. Balsam poplar (Populus balsamifera)	Canker	Valsa sordida	
		Neofabrea populi	
	Leaf blight	Linospora tetraspora	
	Leaf rust	Melampsora spp. (three species)	
	Leaf spots	Marssonina spp. (three species)	
		Septoria musiva	
	Black shoot blight	Venturia populina	
	Trunk rot	Fomes igniarius	a
		Pleurotus spp.	b
	Powder mildew	Uncinula salicis	b

Table 1 (continued)

Tree species (Hosts)	Disease or Symptom	Causal Agent	Importance
E. Bigtooth Aspen (*Populus grandidentata*)	Black shoot blight	*Venturia populina*	b
	Canker	*Dothichiza populea*	
		Cytospora chrysosperma	b
	Leaf spot	*Marssonina castagnei*	
	Leaf rust	*Melampsora* spp.	
	Trunk canker	*Hypoxylon mammatum*	a
	Trunk rot	*Fomes igniarius*	a
	Powdery mildew	*Uncinula salicis*	
F. Quaking Aspen (*Populus tremuloides*)	Barl canker	*Macrophoma tumefaciens*	
	Branch, twig canker	*Dothichiza populea*	
	Black shoot blight	*Venturia tremulae*	b
	Canker	*Nectria galligena*	b
		Cytospora chrysosperma	b
		Hypoxylon mammatum	a,b
	Catkin deformity	*Taphrina johansonii*	
	Ink leafspot	*Ciborinia bifrons*	
	Leaf spot	*Marssonia* spp. (three species)	
		Septoria musiva	
	Leaf rust	*Melampsora* spp. (two species)	

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Table 1 (continued)

Tree species (Hosts)	Disease or Symptom	Causal Agent	Importance
F. Quaking Aspen (continued)	Trunk rot	Fomes igniarius	a,b
		Pleurotus spp. (two species)	b
	Shoestring root rot	Armilaria mellea	a
	Wound rot	Fomes fomentarius	
		Trametes hispida	
	Powdery mildew	Uncinula salicis	b
G. Northern Red Oak (Quercus borealis)	Butt rot	Polyporus sulphureus	b
	Anthracnose	Gloeosporium quercinum	b
	Canker	Nectria galligena	
		Strumella coryneoidea	a,b
	Leaf blister	Taphrina caerulescens	
	Leaf rust	Cronartium quercuum	
	Leaf spot	Septoria quercicola	
	Powdery mildew	Phyllactinia corylea	
	Shoestring root rot	Armillaria mellea	
	Trunk rot	Fomes everhartii	a
		Fomes robustus	a
		Polyporus obtusus	

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Table 1 (continued)

Tree species (Hosts)	Disease or Symptom	Causual Agent	Importance
H. Bur Oak (*Quercus macrocarpa*)	Butt rot	*Polporus sulphureus*	
	Canker	*Strumella coryneoidea* *Physalospora obtusa*	b
	Anthracnose	*Gloeosporium canadense*	b
	Leaf blister	*Taphrina caerulescens*	
	Leaf spot	*Phyllosticta spp.*	
	Shoestring root rot	*Armillaria mellea*	
	Smooth patch of bark	*Aleurodiscus spp.*	b
	Trunk rot	*Daedalia quercina* *Fomes everhartii*	
	Powdery mildew	*Microsphaeria alni*	
I. Mountain Ash (*Sorbus americana*)	Canker	*Cytospora chrysosperma* *Nectria cinnabarina*	
	Fire blight	*Erwinia amylovora*	b
	Leaf rust	*Gymnosporangium auriantiacum*	
	Wound rot	*Polyporus versicolor*	

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Table 1 (continued)

Tree Species (Hosts)	Disease or Symptom	Causual Agent	Importance
J. American Basswood (*Tilia americana*)	Canker	*Nectria spp.*	
	Leaf blight	*Cercospora microsora*	
	Leaf spot	*Gnomonia tiliae*	
	Powdery mildew	*Uncinula clintonii*	
	Trunk rot	*Fomes applanatus*	
		Pleurotus ostreatus	

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BALSAM FIR BUTT ROT

Hosts: Balsam fir, also occuring in white and black spruce

Symptoms: Rot in wood of roots and lower stem, frequently resulting in breakage of lower stem and loss of the tree.

Etiology: Caused primarily by two fungi: Polyporus balsameus and corticium galactinum. The former causes a brown cubical rot; the latter in white stringy rot in wood. Other wood rotting fungi are responsible to a lesser extent (see Polyporus schweinitzii). Both produce sporophores on outside of tree, both before and after death. Spores are wind disseminated. The infection process is uncertain. The mycelia grow in and utilize the heartwood, and hence the fungi are probably not to be considered true parasites.

Importance: Economically important, both from loss of wood in living trees, but perhaps more so because of breakage of trees. Conspicuous because of breakage.

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RUST WITCHES' BROOM OF BALSAM FIR

Hosts: Balsam fir; also reported on white and black spruce (more recently thought to be another broom forming rust, Chrysomyxa arctostaphyli).

Symptoms: Large, conspicuous witches' brooms form in various parts of the crown of the tree, often attaining several feet in diameter. The needles in these brooms may be greenish or yellowish, or they may be dead.

Etiology: Caused by the rust fungus Melampsorella caryophyllacearum. This pathogen produces five spore stages, two of which occur on the tree host, two occurring on Stellaria sp. and one of which occurs apart from a living host. Both hosts are required for the complete life cycle. The spores stages on fir are systemic and perennial, so that both occur on all parts of the broom each growing season. Spores from fir cannot reinfect fir, but rather must infect the alternate host. Brooms are the result of the fungus inducing the host to branch repeatedly in a localized area of the crown, with shortening of internodes. Branch swelling and vertical shoots are also characteristic of brooms.

Importance: Of little or no economic importance. Aesthetically important because of the prevalence of the conspicuous witches' brooms. An interesting native disease.

FOMES PINI TRUNK ROT OF CONIFERS

Hosts: Balsam fir; white and black spruce; jack, red and white pine; and northern white cedar.

Symptoms: The fungus causes wood rot in all parts of the stem. The wood first turns reddish, followed by the appearance of white pockets. Externally, infected trees either exhibit "punky" swollen knots (old branch points on the clear stem) or variable brownish sporocarps with daedaliod or angular pores. Sporocarps range from 5-30 cm in width. Extensive rot can result in breakage of the tree in storms.

Etiology: Caused by the basidiomycete Fomes pini. Infection by basidiospores is probably via wounds. Living trees are generally infected, but the fungus continues to live in trees after death. Basidiospores are wind-disseminated. Sporocarps are perennial.

Importance: Of economic importance in most conifer species, causing both loss of heartwood and loss of entire trees. Most prevalent and obvious in old-growth trees, being one of the chief agents responsible for their demise.

BUTT AND ROOT ROT OF CONIFERS

Hosts: Larch; white and black spruce; red, white and jack pines; and northern white cedar.

Symptoms: The fungus grows in and rots the heartwood of the large roots and lower stem, rarely extending upward farther than the first five meters. The wood fractures into red-brown cubicle blocks. Later thin white sheets of mycelium develop in the fractures. Sporocarps often grow upward from underground roots, away from the trunk. They are centrally-stemmed in such locations, with concentric zones of rust and brown. On logs or trunks the sporocarps are shelflike and pores are daedaloid. They are leathery in consistency. No other external symptoms are noteworthy.

Etiology: Caused by the basidiomycete fungus Polyporus schweinitzii. Basidiospores, produced throughout the summer, are wind disseminated. Infection occurs in wounds. Rot progresses very slowly through the butt. Sporocarps are annual, being produced nearly every year.

Importance. Of economic importance in that trees that are severely rotted are subject to breakage or windthrow. Particularly important in large, overmature trees, where sporocarps are easily found following damp weather. A common fleshy fungus in most parts of northern Minnesota. The wide host range of the fungus makes it perhaps more significant in mixed coniferous stands.

DWARFMISTLETOE

Hosts: Black spruce and sometimes larch; occasionally on white spruce and rare on jackpine.

Symptoms: Infected trees exhibit broom formation (dense regions of branches and twigs) usually in irregular patterns. Trees are eventually killed, but often heavily infected portions of the crown die earlier. Dwarfmistletoe occurs in distinct foci of infection rather than scattered distribution. Trees in the center of such foci are dead (or absent), while at the edges and among younger understory trees in or near the center, brooming and distorted growth are evident. Infection occurs in all parts of the crown.

Etiology: Caused by the parasitic, leafless seed plant Arceuthobium pusillum. Infection occurs in twigs, and the plants develop haustoria in the branch tissue and short stemmed, greenish yellow shoots topped by male or female flowers. Seeds are forcibly discharged about 15-30 feet, and are coated with sticky mucilage. Long distance dissemination is probably by birds.

Importance: Of considerable economic importance in black spruce but not in other species. Quite conspicious in black spruce bogs. Common in all parts of northern Minnesota. Slow rate of spread both within foci and for long distances, makes dwarfmistletoe a unique sort of disease, one that can be carefully observed from year to year.

SPRUCE NEEDLE RUSTS

Hosts: White spruce, black spruce

Symptoms: Needles become covered with light orange, cushion like pustules that rupture to release white aeciospores. The entire tree can take on a yellowish appearance due to prevalance of light pustules. Clouds of dust-like spores will rise if branches containing mature aecia are shaken.

Etiology: Caused by three species of rust fungi (1) Chrysomyxa cassandrae, (2) C. ledicola, and (3) C. ledi. All 3 occur on black spruce, while only (1) and (2) have been found on white spruce. All have alternate hosts: (1) on Chamaedaphne calyculata (leatherleaf); (2) and (3) on Ledum groenlandicum (labrador tea). Two spore stages occur on these hosts, while both pycnial (short lived and inconspicous) and aecial stages occur on spruce. Both spruce and the alternate host are required for completion of the life cycle of each rust. Aeciospores cannot reinfect spruce.

Importance: Of no economic importance. Probably does not kill spruce trees. Quite conspicious and spectacular when weather is favorable for rust infection.

EASTERN GALL RUST

Hosts: Jack pine (occasionally on red pine), Northern red oak

Symptoms: Pine: infection of smaller branches results in the formation of spherical galls that completely surround the stem. Galls on the stems of older trees frequently include only part of the stem's circumference, or appear as flat or distorted areas on the stem. Light orange aeciospores and orange droplets of pycniospores appear on these galls. Oak: infection is on leaves as small necrotic areas. On the undersides, either orange uredia or brown, hair-like telial columns are seen in the centers of the necrotic areas. Leaves can be covered by thousands of such lesions.

Etiology: Caused by the rust fungus Cronartium quercuum, which exhibits a complex life cycle. Telial columns germinate on dead oak leaves in early summer, to produce basidiospores that are carried to pine needles. Galls form about a year later, and produce pycnia the next year. Fertilization of sexual pycnia results in aecia the following year. Aeciospores travel by wind to oak, where infection results first in uredia, turning later to telia.

Importance: Can be lethal to seedlings and young jack pine trees via galls formed on main stems. Branch galls on larger trees are common and conspicuous, but of little or no economic importance. Very common on jack pine throughout northern Minnesota. A well-adapted parasitic member of the native flora, that could be useful in thinning often characteristic overly dense stands of young jack pine.

SCLERODERRIS CANKER

Hosts: Red pine and jack pine

Symptoms: A yellow-green color is evident beneath the bark of infected trees. In April and May the bases of needles turn brown and the needles fall from the tree. Stem cankers are another symptom but are not always obvious. Presently only young trees are severely affected.

Etiology: Caused by the Ascomycete fungus Scleroderris lagerbergii. Infection seems to occur in natural wounds and openings, such as frost injuries. Ascospores are produced in apothecia on the branches, and these are wind dispersed during wet weather throughout the growing season. Initial infection is in fall, and apothecia form two seasons later. Conidia are also produced that probably are important in local infections of the same tree. The disease is spread also by man, when diseased nursery stock is transported long distances.

Importance: At present of little importance in natural stands of pine. Very recently, a new strain of the fungus has been found in New York state. This strain, presumably of European origin, is capable of rapidly killing full-sized red pines via multiple canker infection. If it arrives in Minnesota, in the future, it could conceivably destroy all red pine and do severe damage to the somewhat less susceptible jack pine. Undoubtedly this is the most serious disease threat of all time for Minnesota forests.

WHITE PINE BLISTER RUST

Hosts: White pine

Symptoms: Cankers are formed on branches of all sizes. On stems, these cankers are sunken diamond shaped or oval areas that slowly grow, eventually girdling the stem and killing the tree. White streaks and drops of pitch are nearly always associated with cankers. Girdled branches are also killed, resulting in conspicuous dead, brown "flags".

Etiology: Caused by the rust fungus Cronartium ribicola. The alternate hosts are any of several species of Ribes. Infection of pines is by basidiospores, that germinate and grow in the needles, then down to the twig where cankers form. The mycelium continues to grow toward the main stem, where the significant cankers are formed. Orange, sticky pycnia and light orange blisterlike aecia form 3-6 years after infection, and every year thereafter as canker grows. Aeciospores are wind-disseminated and infect Ribes leaves to produce uredia. Urediospores can reinfect Ribes, but, toward late summer, brown telial columns form and produce basidiospores which travel to and infect pine.

Importance: Undoubtedly the most economically important and conspicuous disease of white pine. Abundant everywhere. In Minnesota, due to prevalence of Ribes it is most serious in the northeast. A limiting factor in white pine forestry. Originally from Asia.

NECTRIA CANKER

Hosts: Red maple, bigtooth aspen, quaking aspen, paper birch, northern red oak, mountain ash, American basswood.

Symptoms: Cankers are usually oval or elliptical with many successive layers of callus tissue, giving a concentric "target" appearance. Aspen, however, shows an irregular canker whose face is usually covered with bark. A branch stub often occurs in the center of the canker. Cankers can occur on branches on the main stem.

Etiology: Caused by two species of Nectria, N. galligena (all species except mountain ash) and N. cinnabarina (mountain ash and basswood). These ascomycete fungi produce two spore types on the cankers: water-disseminated conidia and wind-disseminated ascospores. Infection probably occurs in wounds. The mycelium in the canker is perennial. The fungi survive and sporulate also on dead bark and wood. Trees growing on poor sites tend to sustain more infections. Old trees probably are not susceptible.

Importance: Capable of killing trees, or, more commonly, adversely affecting their growth form. Very conspicuous in stands of birch and aspen, and on red maple in northeastern Minnesota, partly because the fungi do not quickly destroy, and hence eliminate, infected host individuals.

EUTYPELLA CANKER OF RED MAPLE

Hosts: Red maple

Symptoms: Cankers occur generally on the main stem from the ground up to about 10 feet. They appear as heavily callused, concentrically-ringed circular or oval sunken areas with patches of bark adhering to the surface.

Etiology: Caused by the ascomycete fungus Eutypella parasitica. A dead branch stub at the center of each canker probably indicates initial infection in the branch. The mycelium can be found as fans on the canker's periphery. Ascospores are disseminated from black perithecia in the bark. Details of infection and spread are not known.

Importance: Of little economic importance because of relative unimportance of red maple. Capable of causing loss in the species, both by killing trees indirectly and by allowing wood-rotting fungi to enter. Since small trees are readily killed, it may affect the reproduction and hence prevalence of red maple in some cases. Common and conspicuous.

SHOESTRING ROOT ROT

Hosts: nearly all species of trees; all age classes.

Symptoms: Root and lower stem rot, indicated by death of either portions of a tree's crown or the entire crown. Crown death is particularly noticeable when a period of drought follows a long spell of adequate moisture. This occurs because the amount of healthy root is sufficient only to support the crown under non-stress conditions. Leaves of deciduous trees wilt and turn brown. Conifer needles turn brown over a period of weeks, under conditions favoring the disease.

Etiology: Caused by the mushroom-forming fungus Armillaria mellea. The pathogen spreads through soil via black, shoestring-like vegetative structures called rhizomorphs. Spread is from colonized dead wood to living roots. Mats or fans of mycelium form in the inner bark and between bark and sapwood of infected roots. Rhizomorphs accompany these fans, extending far up the trunk, in hardwoods. Mushrooms occur around colonized and killed host plants. Spores cannot directly affect living hosts, but rather colonize dead wood saprophytically. An agressive saprophyte.

Importance: Very common in Minnesota, and undoubtedly important as a tree pathogen nearly everywhere. Most apparently important where trees occur in marginal or inappropriate sites, or where they have been adversely affected by their environment. A substantial share of dead and dying trees in the forest will be found to have mats of A. mellea on their roots. In some cases, these may be the result of secondary invasion by the pathogen.

TRUNK ROT AND CANKER

Hosts: Paper birch

Symptoms: Large distinctive black, irregular, swollen "clinker like" mass of fungus and callus tissue on the main stem comprise the cankers. Heart rot of the wood accompanies the canker and is usually extensive.

Etiology: Caused by the basidiomycete fungus Poria obliqua. Life cycle and ecology not well understood. Sporophores produced on dead trees. Basidiospores airborne.

Importance: Of some economic importance as a heart rotter of living birch. Fairly common, and quite conspicuous on birch, usually eliciting negative reactions because of the amorphous appearance of the cankers.

BIRCH DIEBACK

Hosts: Paper birch

Symptoms: First appears as thinning foliage, with curled or chlorotic, leaves at shoot tips, followed by total defoliation of branches and entire crowns. The dieback then spreads in area, if severe. Dieback can be very localized also.

Etiology: Most probably a nonparasitic disease. Dieback may be hastened by a virus disease or by bronze birch borer. Its chief cause, however, is a sudden rise in soil temperature. An average increase of 4°F is sufficient to cause rootlet mortality followed by general decline in the crown and dieback. Anything that contributes to this rise in temperature, such as opening of a stand, can trigger dieback. Higher than average temperatures and low moisture are also contributory. Shallow rooting of birch is thought to be a major reason why the species is so sensitive to such factors.

Importance: Has been very destructive in various areas in the past. In Minnesota, mostly localized where logging has removed over 40% of the stand. Potentially a problem anywhere that birch grows, and where sudden changes occur in mixed or pure stands, whatever the reason.

TRUNK ROT OF BIRCH

Hosts: Paper birch, occasional on quaking aspen.

Symptoms: A wood-rotting basidiomycete fungus. Distinctive deep, grayish conks are abundantly produced on trunks of living or dead trees.

Etiology: Caused by the fungus Fomes fomentarius spread by airborne basidiospores. Wounding is required for infection of living trees. Conks are perennial and release spores throughout the growing season.

Importance: Not an important live-tree wood-rotter because its usual habitat is dead trees. Extremely abundant and conspicuous.

HEART ROT OF ASH

Hosts: Black ash

Symptoms: Conks occur at all levels on main stems and large branches of trees. They are hoof-shaped with creamy pore surfaces and gray-black tops. They signify that the heartwood is extensively decayed, the wood being delignified and appearing whitish and fibrous.

Etiology: Caused by the basidiomycete fungus Fomes fraxinophilus. The fungus nearly always begins in living trees, on which most conks are observed. Infection probably requires wounds. Conks are perennial and shed basidiospores all through the growing season for several years. Basidiospores are wind-disseminated. Rot spreads slowly but steadily throughout the trunk.

Importance: Of some economic importance due to loss of wood. Not particularly destructive in terms of breakage of trees. Conks are especially conspicuous and abundant in old, pure stands of black ash and the accompanying rot results in numerous hollow trees which might have value for wildlife.

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Black shoot blight of poplars

Hosts: Quaking aspen, bigtooth aspen, balsam poplar

Symptoms: Shoots and developing leaves are attacked. Affected tissues are black and brittle with tips of leaves curled. Shoots often appear crooked or deformed. Symptoms are most evident in spring. Small trees are more heavily attacked. Extent of infection varies considerably among shoots.

Etiology: Caused by two species of the ascomycete genera Venturia, V. populina (on bigtooth and balsam poplars) and V. tremulae (on quaking aspen). Both species have imperfect stages in the form-genus Pollaccia. Primary infection in May is by ascospores from old, blighted tissues. Secondary infection, starting in June, is by conidia from blighted shoots. Both spore stages require wet weather, although they are wind disseminated.

Importance: Of no economic importance. Quite conspicuous in early summer, especially if secondary spread has been favored by frequent rainy periods.

CYTOSPORA CANKER

Hosts: Quaking aspen, paper birch, balsam poplar

Symptoms: Cytospora cankers develop by the gradual killing of bark in an elliptical pattern, usually with bark remaining attached. Often a branch stub occurs in the center of the canker. Callus tissue frequently forms at the edge of the invaded region, giving a ridge around the center. Discoloration and a sunken appearance also are typical. Masses of black, "pimple" like pycnidia are abundant in the dead bark. These may have elongated orange masses of conidia extending from them, especially during or after, moist weather.

Etiology: Caused by the imperfect fungus Cytospora chrysosperma (and sometimes other Cytospora species). It is called Valsa sordida in the perfect stage, although this is rarely found. Conidia are spread by rain, wind, and insects. Infection is through wounds and dead wood, and the bark and outer sapwood are invaded and killed.

Importance: Of greatest occurrence where trees are growing in poor or inappropriate sites, or are otherwise predisposed. A ubiquitous fungus that also colonizes dead wood. Fairly conspicuous on aspen everywhere. Less so on other species, usually. Otherwise of little importance.

HYPOXYLON CANKER OF ASPEN

Hosts: Quaking aspen, occasionally on bigtooth aspen and red maple.

Symptoms: Cankers are fast-growing and diffuse, approaching 10 ft. in length on large trees. Cankers are associated with a branch stub or dead branch. The bark turns yellow and mottled. A few weeks after infection the bark surface collapses irregularly. Later the bark in the center of the canker breaks up. On cankers over 3 years old, black and gray perithecia form on the wood where the bark is broken. Tiny masses of conidia can be seen on the margins of the canker. Cankers can occur at all levels of the stem or on branches.

Etiology: Caused by the ascomycete fungus Hypoxylon mammatum. Infection is by wind-borne ascospores produced in the perithecia. Insect wounds or other sorts of injury are necessary. Insects may carry spores into inner bark and wood. The fungus grows so rapidly through wood and bark that the tree is usually unable to produce callus tissue. Girdling and death occur after several years. Conidia do not function in infection, but rather in the sexual process of the parasite. Perithecia release ascospores throughout the spring, summer, fall, and even in winter.

Importance: Very destructive to quaking aspen. Cankers result in eventual tree death, but also allow breakage in windstorms, due to rotting of wood by the pathogen. More prevalent in aspen stands growing on poor sites, making such stands unsightly. A ubiquitous disease where ever the hosts occur. In sample plots, 24% of the trees were infected or killed by Hypoxylon.

TRUNK ROT OF ASPEN

Hosts: Quaking aspen, bigtooth aspen, balsam poplar, also on birch and maple.

Symptoms: The heartwood is rotted, turning uniformly whitish-buff. In advanced stages a black, zone line separates decayed from healthy wood. Decay occurs usually in the middle, rather than in the butt or top ends of the stem. Black and brown hoof-shaped sporocarps or swollen knots are the external symptoms of decay, usually high on the stem.

Etiology: Caused by the basidiomycete fungus Fomes igniarius. Infection is via basidiopores that land on freshly exposed wood surfaces, such as occur with wounds. The mycelium progresses slowly throughout the wood. When sporocarps appear, the trunk is extensively rotted for a considerable distance. above and below each conk. Perennial conks release numerous basidiospores throughout the growing season.

Importance: Quite common, especially in older stands of aspen. The most important cause of decay in aspen. An infected stand will suffer much breakage in high winds. Sporocarps are conspicuous, often seemingly on every tree in the stand. A definite limiting factor in determining economic rotation age in timber management.

Pleurotus trunk rot

Hosts: Quaking aspen

Symptoms: Causes a sap and heartwood rot in living aspens. Most evident from its distinctive whitish, fleshy, gilled imbricate sporophores that are of large size and grow from the sides of the trunk.

Etiology: Caused by two similar species of the mushroom-forming basidiomycete genus Pleurotus. These fungi usually colonize dead or dying aspen. Infection is by wind-disseminated basidiospores that are released in large numbers from short-lived sporophores that grow on the trunk of the tree or log after heavy rains. Infection of living trees is via wounds.

Importance: Of economic importance mainly through loss of wood in dead timber. Because of size and abundance of sporophores the pathogens are quite conspicuous during the summer.

POWDERY MILDEW OF ASPEN AND WILLOW

Hosts: Quaking aspen, bigtooth aspen, and balsam poplar. Also on species of willows.

Symptoms: A leaf disease. In late summer, white powdery spots appear on leaves, and eventually coalesce and cover most upper leaf surfaces. When leaves begin to senesce and turn yellow, small black spherical structures, called perithecia, appear scattered on upper leaf surfaces.

Etiology: Caused by the ascomycete fungus Uncinula salicis. A superficial parasite of leaf epidermal cells. Infection in spring and summer is by ascospores. The powdery stage is really masses of hyphae and conidia, that are wind disseminated to spread the disease. Overwinters as ascospores within perithecia on dead leaves.

Importance: Of no real harm to the tree. A conspicuous parasitic member of the fungus flora.

STRUMELLA CANKER

Hosts: Northern red oak

Symptoms: Cankers are target shaped due to ridges of callus tissue, ranging from a few inches to 8 feet in length. Bark usually remains intact over the surface of the canker. The stem or limb characteristically bulges on the side opposite the canker. Small black fruiting structures form on the face of the canker. Cankers are often near the base of the tree.

Etiology: Caused by the imperfect fungus Strumella coryneoidea (perfect stage Urnula crateritium, an ascomycete). Infection occurs in branch axils, from which mycelia spread outward. Conidia are produced on black sporodochia. They and the ascospores are wind-disseminated.

Importance: Cankers occur on all ages of trees. The fungus rarely kills the host directly, but since wood beneath is rotted, breakage of the stem is common. Cankers are particularly large and unsightly, making them quite noticeable.

TRUNK ROT OF OAK

Hosts: Northern oak, bur oak

Symptoms: Sporophores are either large and hoof-shaped, with cracked grayish tops and brown pore surfaces (Fomes everhartii) or flat, brown, non-shelf-like areas with little or no definite shape or sterile surface (F. robustus). Both organisms cause a whitish, delignifying decay of heartwood.

Etiology: Caused by the basidiomycete fungi Fomes exerhartii and F. robustus. Basidiospores are released in great numbers from the sporocarps throughout the season. They are wind disseminated and enter the host through wounds. Development of the rot is gradual, requiring several years before sporocarps are again produced.

Importance: Of economic importance only in loss of timber value. Not often resulting in breakage of the tree. Fruiting bodies fairly conspicuous especially on large trees.

FIRE BLIGHT OF MOUNTAIN ASH

Hosts: Mountain ash

Symptoms: All portions of the tree are attacked. Symptoms are most evident, however, on succulent sprout growth, which turns to a brown or black color and wilts. The branches and leaves appear scorched and cracked as though they had been near a fire. Lesions on fruit and cankers on branches may also be seen. Infected tissues, when sliced, exude large quantities of bacterial cells.

Etiology: Caused by the bacterium Erwinia amylovora. The pathogen overwinters in old, perennial cankers on stems or twigs. During the spring, the bacteria ooze from these cankers and are transferred to blossoms by insects. More local dissemination occurs when rain splashes the bacteria to blossoms where infection occurs. The pathogen spreads within the branch through intercellular spaces.

Importance: Mountain ash is quite susceptible to this disease, and it can kill a tree in a single season if conditions are favorable. Overall, not very destructive to native mountain ash.

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