DISEASE PROBLEMS OF POPLAR IN THE WESTERN INTERIOR OF CANADA

by

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INTRODUCTION

Diseases are common in native and hybrid poplar, frequently inflicting heavy damage (Baranyay, 1964) both in the nursery and after planting out. Several, such as winter injury, mechanical damage, hail, and fire, are non-infectious diseases. The cankers resulting from these injuries are often confused with septoria canker caused by the fungus *Septoria musiva* Pk. Or their cause is often ascribed to another fungus, *Cytospora chrysosperma* Fr. (Cram, 1960). This report deals largely with diseases of poplar, many of which can be rectified if the cause of primary injury is correctly identified. The sources of information are research, personal experience, and literature review.

Characteristically, poplars are shallow rooted (2 to 6 inches), relatively short lived (40 to 60 years) and have only a short growing period of 30 to 50 days. Current year's shoots attain maximum growth in the early summer months and produce seed in the spring of the following year. Trees bear fruit at an early age of 6 years.

Balsam poplar, *Populus balsamifera* L., black cottonwood, *P. trichocarpa* Torr. & Gray, and plains cottonwood, *P. deltoides* Marsh. var. *occidentalis* Rydb., when sheltered grow best in moist alluvial soils, and

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they provide the inter- and intraspecific clones of hybrids that are valued for shelterbelt and parks planting. The oldest hybrids that have been used over the years for planting out in shelterbelts are Northwest poplar and Russian poplar, but the list has been expanded in recent years by the Federal and Provincial Nurseries (see Appendix A). The shoots of these poplars do not begin to elongate rapidly until after June 18, and some clones as late as the first week in July. This becomes an important consideration in disease development and for cultural practices.

Aspen, P. tremuloides Michx., grows best on well-drained loam, but it is commonly found on widely varied soils. It suckers profusely from roots on clear-cut or burnt-over sites, but it does not propogate well from stem cuttings. Many of the early clones seed May 18 and later clones June 5 to 7. Therefore, shoot elongation is earlier and the growing period is longer than in balsam poplar or cottonwoods. Naturally occuring hybrids are not available for planting purposes in shelterbelts.

In poplar, the vital tissues of the bark and sapwood become damaged readily by winter drying (Wilner, 1952; Sakai et al., 1967) and by desiccation when impaired roots are unable to take up moisture. During rapid growth of poplar in July, injuries to these tissues should heal readily, except in trees too weak to survive deficiencies in moisture and food or continual root disturbance. During growth reduction and cessation, injuries often fail to heal completely and become centers of canker activity.

This report discusses the background to underlying causes of serious disease-problems in nurseries, plantations, and shelterbelts. A photoguide (Appendix B) provides additional information on symptomatology of each disease listed in heading below and accompanied by figure numbers. Examination of many unthrifty poplars and many cankers over a period of years by isolation, inoculation, and microscopic techniques suggests that problems initiated by pathogenic organisms are relatively rare. Far more common are injuries of non-biological causes, especially frost or bad weather, mechanical, fire, or combinations of these.

WINTER INJURY (Figures 1-17)

General

Winter injury is common to clones of hybrid poplar in nursery stooling beds and in planted as well as in natural stands. When poplar roots, sapwood, and bark are exposed to freezing and thawing during early and late winter and in chinook areas throughout the winter, injury to these tissues may result. Sudden changes in temperatures during this time can kill limbs, leaders, and even entire trees. Cause of death is difficult to diagnose because symptoms of dieback are delayed by several months (Hord et al., 1957; Parker, 1965; Zalasky et al., 1968). Table 1 summarizes the relative incidence of dieback in two plantings of several clones of hybrid poplar.

Current Shoots

Some clones of poplar fail to produce sufficient summerwood in the current shoots, which therefore remain susceptible to frost when winter comes (Zalasky et al., 1968). As a result, symptoms of tip dieback appear rapidly; aerial parts are directly affected (Table 1) in early and late winter if extreme fluctuations in temperatures prevail. Affected tips turn a straw-color and have a scar of healing tissue at their bases. Injury to terminal parts is frequent during the early years of establishment of poplar clones in plantations, shelterbelts, and nurseries producing saleable stock.

Table 1. Incidence of dieback due to winter injury to poplar species and hybrids

Clones	No. of trees	Intensity*	Distribution*	Incidence*
Plot MS-510 (1965) Hadashville, Manitoba; 1965-1966 to 1967-1968				
P. 'berolinensis'	4	16	13	3.6
P. 'Brooks #1'	4	12	8	2.5
P. 'cardeniensis'	5	19	13	3.2
P. deltoides var. occidentalis	3	19	18	6.1
P. FNS #44-52	2	5	5	2.5
P. 'Gelrica'	5	34	30	6.4
P. 'Northwest'	3	8	6	2.3
P. petrowskyana	4	6	4	1.2
P. 'Saskatchewan'	4	6	4	1.2
P. tristis	4	22	12	4.2
P. 'Vernirubens'	2	8	10	4.5
P. 'Volunteer'	4	0	0	0.0
Outlook, Saskatchewan 1968-1969				
P. 'FNS #4452 (1964 Plantation)	200	79	114	0.48

* See Appendix C

Roots

Frost damage to roots, which causes injury and death, occurs when there is insufficient snow cover to insulate the shallow roots from severe winter temperatures. Root damage weakens trees, often preventing a flush of leaves in the spring, and results in severe dieback of leaders and branches during late spring and early summer. New leaders fail to develop, and "staghead" trees are common. Some weak branches bear small leaves and spindly twigs that often wilt and die. However, unlike in the previously described shoot dieback, dead limbs do not discolor or have a basal scar of healing tissue. Some clones suffering a setback in the first few years after transplanting often fail to establish. Trees of all ages are susceptible to root killing. This injury occurs only under specific winter conditions, usually with an intermediate period of winters without damage, so that one must be on guard to spot signs of trouble in the early or late spring following winters during which damaging conditions existed.

Stem or Bark

Adverse weather conditions acting in combination, e.g., severe late winter followed by unusually dry spring and early summer, may result in considerable damage. Inconspicuous blistering of the bark occurs on the trunk and bases of branches. During dry winds, the injured parts of the tree dry rapidly and discolor. The blisters break in dead patches and the periderm peels off the bark. These injuries result in trunk canker and basal-branch girdling. As the tree grows in successive seasons, the canker is surrounded by poorly differentiated sapwood under the dead bark but the healing tissues often remain immature and frost-susceptible, failing to survive through the following winter. Old cankers are distinguished by their broad central exposed wood surface and protruding black ridges of terrace-like woody calluses. The histology of such cankers in hardwood forest trees, fruit trees, and ornamentals is well documented by Sorauer (1914). Trees affected this way may be girdled and killed if no effective remedies (see following section) are implemented.

Another common symptom of late-winter injury are frost cracks in March and April. The frost cracks vary in length from a few inches to over 10 ft. If the tree is healthy and conditions are good, these cracks heal during the summer. Under unfavorable conditions, especially during mild spells with temperatures above 41 F (Wilner, 1952), the living tissues of the bark exposed by frost cracks may weaken, dry out, and die. The first signs of cankering appear when the bark begins to split, discolor, and lift. Frequently, new sapwood around the margin of the frost crack develops too slowly or too late in the growing season to cover the initial canker; or it forms in the mid-region and causes dead bark to become raised, loosened, and sloughed away. The open wound makes the weakened bark at the margins vulnerable to further drying during prolonged unfavorable conditions, or to further winter injury to the frost-susceptible healing tissues.

Cankers resulting from winter injury occur on most poplars older than 5 years. They vary in sizes and shapes, but are usually spear-head shaped. Some cankers are very wide and long and persist for many years. These are readily recognized by the concentric ridges of old sapwood, visible after the bark has sloughed away. Limbs of affected trees usually die back to the cankers and eventually lose their bark completely. In "staghead" trees, they may be present for a long time before they are broken.

After winter injury, leafing out is much delayed and twig abscission may be severe. Leaves are small, scorched, and often do not remain on the affected limbs for the whole summer. New shoots are spindly, weak, chlorotic, and do not harden properly before the onset of winter. Suckers and bud-brooming occur profusely around cankers and basally on the main stem but weak and late shoots usually winter-kill.

Fungal Succession

Dead bark and shoots are usually inhabited by higher Fungi, either wound parasites or saprophytes. Common after winter injury are *Cytospora chrysosperma* Fr. (Morgeneyer, 1960; Zalasky *et al.*, 1968), *Nectria galligena* Bres., and *Hypoxylon mammatum* (Wahl.) Miller.

Stooling Beds

Winter-drying injury (Cayford *et al.*, 1959) is common in nursery stooling beds after initial pruning and after harvest of current whips for cutting in October. Because temperatures during this time are often above 41 F, the injury is similar to that described by Wilner (1952) for cuttings in storage. The stems at the exposed cut ends dry and the bark discolors, which results each year in dieback, reduction of potential shoot-producing buds, and rapid decline in vigor of stooling stock.

General Treatment for Winter Injury

Wherever practicable, fall and spring irrigation should be practised to reduce winter-killing and protect planted trees against dryness. If trees show signs of distress, dieback, or cankering in late spring, a light application of nitrogen-phosphorus fertilizer (11-48-00) followed by abundant watering would help trees to regain vigor and aid in rapid healing of cankers and better recovery. Killed shoots and branches of young trees should be pruned back in early spring for proper sanitation and for retraining to correct the form of the tree.

MECHANICAL DAMAGE (Figures 18-24)

Mechanical damages to bark and main roots are common in plantations of hybrid poplar maintained free of weeds or in parks and recreational areas where natural sites are prepared and developed for camping and picnicking. These damages are aggravated by adverse weather and poor growing conditions. Cultural practices such as close cultivation (Baranyay, 1964) for weed control, and trenching and bulldozing for road-beds and driveways may cause considerable damage by scraping, severing, or bruising roots of these shallow-rooted trees. The main roots within a radius of 3 to 4 feet are frequently only 2 to 4 inches beneath the ground and hence are very vulnerable to damage during cultivation. In most sites, severe root damage is accompanied by winter-drying, desiccation of bark, loss of tree vigor, cankering, and dieback. Female trees in seed are most adversely affected and may die if desiccation of bark on the main trunk results in girdling. Many trees respond by profuse suckering at the lower half of the trunk. Damage is irreparable except by pruning the tree back to the ground and training a single sucker.

In plantations and natural forests designated as recreational and camping areas, heavy mechanical equipment in the form of tracked vehicles, scrapers, and rotovators are used to provide necessary facilities. Extensive and permanent damage to shallow roots may occur with resulting dieback and decay of residual trees. Great care must be taken to ensure that the trees, often the main attraction in the area, are not destroyed in the process of establishing the park. A good understanding of the ecology of the stand, wise design of facilities, and use of light construction-vehicles will frequently relieve park managers of future problems with their trees.

The rotovator, rototiller, one-way disc plow and duckfoot cultivator, if operated without sufficient care, may cause lasting damage to trees. Discs and plows are capable of severing the main roots into short pieces from which suckers may develop. Rototillers may be particularly damaging when trees are young with thin main roots. The heavier and more powerful rotovator can pulverize and destroy most roots regardless of their age and size. Duckfoot cultivators often lift the main roots and leave them exposed, or scalp the bark from the top surface.

Equipment operated too close to trees will often scrape, bruise, and split the bark at the base of trunks. Trunk-splitting caused by hooking branches or main roots and lifting of large strips of bark will result in permanent damage. Loose bark commonly occurring at the base of older trees may have its origin from injuries during cultivation followed by accumulation of ice under the bark during freezing and thawing in late winter.

FIRE INJURY (Figures 25-45)

Fire can be quite injurious to juvenile and pole-sized trees which most commonly have thin and succulent bark. Carelessness can lead to total loss of a shelterbelt or a natural stand. Some types of damage often encountered may go unnoticed by laymen for several days or weeks, especially when no charring effects are discernible. The trees usually leaf out briefly.

The severity of the injury varies with the type and amount of fuel. The intensity of the heat generated may also change with changes in wind velocity. Fire hazard is greatest in the spring before new grass and herbs cover the site.

Fire injury is common in certain districts where fire is used for sanitation and cleaning up of stubble, dead weeds and grass, leaves, and accumulated litter. Injury arises from flames or wind-blown, intensely hot air that sear the bark in short or long strips, often along one side, or frequently girdling the base of the tree. The extent of injury varies from a few inches to a few feet above the ground.

Several days later, droplets of light amber to brown gum ooze out of pinhead openings in the bark where hot steam and gases escaped from under the periderm. Several days elapse before the injured bark of juvenile poplar changes from a smoked green to a light bronze and yellowish-orange. Damaged bark gradually collapses as it dries, becomes cankered, and the periderm turns gray and scaly. Typical cankers are elongate, elliptic, and with a gradual taper at the top. Usually, there is no basal charring in juvenile trees, except from very severe burns. Some basal charring and girdling occurs in pole-sized trees, in which dry, thickened cork acts as its own fuel. Spots of smoldering cork generate enough heat to penetrate the phloem area and kill the cambium and sapwood. Girdled trees die after leafing out or in the following spring.

Some shelterbelt and farmstead plantings have close understory plantings of caragana and Manitoba maple that act as additional fuels. Fire reaches an intensity hot enough and with duration long enough to kill or damage mature trees. The flames envelop the stems, blister and char the cortex in scattered pock marks, and, occasionally,when they reach into the branches, the whole tree may burn to a charred stump. The damage may seem negligible at first; most trees with basal injury may leaf out - others fail or only portions of the tree leaf out. The slow process of drying of the bark and sapwood takes place where the cambium had been killed. The dry bark soon cracks in long, vertical strips and peels clear to the wood, leaving the trunk and branches bare. Russian poplar and Northwest poplar examined by the author show no signs of suckering from roots as native poplars normally do after a burn. However, trees incompletely girdled at the trunk will sucker from the living sapwood in the lower half of the trunk.

During development of natural camping and picnic areas in parks and along roadsides, it is important to take precautionary measures when clearing brush. Otherwise, indiscriminate and careless use of fire may result in a costly loss of natural attraction to the site and subsequent investment in time and manpower or later replacement of trees.

HAIL DAMAGE (Figures 46-48)

Heavy hail storms occurring between May and September (Anon., 1969; Renick, 1969) may cause severe damage to poplars of all ages. The bruising effect generally occurs only on one side of the tree, that side from which hail stones came (Riley, 1953). If the hail damage is in July, the wounds will likely heal that year. Rate of healing depends on the weather, growing conditions, and general vigor of the tree. Drought followed by severe winter creates conditions conducive to open-canker formation particularly in the crotches of branches. Dieback is a common symptom in hail-damaged stands.

Severe hail accompanied by high winds causes considerable defoliation, bark wounding, and, often, total severing of leaders. Exposed, closely branched trees are particularly vulnerable.

DAMAGES BY (BUD) GALL MITES, INSECTS, AND RODENTS (Figures 49-51)

Gall mites are prevalent on suppressed, weak trees that have been previously injured by climatic or mechanical processes. Mite infestations help perpetuate a weak, stunted condition in trees.

Small galls in the upper branches are often caused by a species of wood borer (Saperda sp.). When the larva leaves the gall, the wound in the limb usually heals. However, in unthrifty trees, galls fail to heal and this initiates formation of open cankers that remain for long periods. They have irregular shapes and flaring margins with fraying bark, and these differentiate them from cankers covered by winter injury. The cankers are black, usually shorter and smaller and always occur on branches but occasionally on the leader.

Rodent damage is common in stools. Mice feed on the bark at ground level and several inches above, under the cover of snow. Rabbits damage the trees usually above the snow line. There are many dead poplars killed by girdling in plantations of southern Saskatchewan.

SEPTORIA CANKER (Figures 52-55)

The fungus Septoria musiva Pk. (Bier, 1967) infects early-season foliage in June or July. Secondary inoculum produced on the leaves may occasionally re-infect the stem through the thin bark or through the petioles. The lower parts of vigorous long shoots, epicormic branches, sprouts, and suckers 1 to 3 years old are particularly susceptible to infection late in the season after infected June leaves have produced sufficient inoculum for dispersal. Short lateral shoots (brachyblasts) and long terminal shoots (turions) in the upper parts of a juvenile tree usually escape infection. Late season leaf infections do not produce enough spore inoculum to infect stems in late summer or in the following spring. The first cankers on 1-year-old shoots are small, elongate, dark brown, necrotic, frequently with a pale, collapsed center in which numerous pycnidia are formed. Occasionally, a pale chlorotic band may surround the canker. In most cankers, marginal swellings occur in the following summer when new sapwood is formed. These result in small, confined cankers or in spindle-shaped cankers occurring on main branches, rarely on main stems. No "target" cankers occur because the bark and woody tissues within the canker dry and the fungus is soon destroyed by saprophytes. In a vigorous, growing tree, a new leader may readily replace a cankered one within a year.

Septoria canker is particularly important in nurseries. It greatly reduces the quality of marketable rooted stock and whips for cuttings. In stooling beds, whips of Northwest and Russian poplar are prone to incidence of canker (Table 2). Distribution of infected rooted stock accelerates dissemination of this important disease-causing fungus. Weak, diseased trees generally fail to develop proper stem and crown form, require early corrective measures by pruning and training, and eventually may have to be replaced if they become unthrifty under abnormal conditions. Although the fungus is critical in regeneration material and in a few young plantations, there is no known risk in fully established or mature trees even when inoculum is abundant on suckers and juvenile trees. Risk of infection is higher when 1- and 2-year-old whips are planted next to existing infections where the inoculum potential is high. Table 3 shows the relative incidence of

Table 2. Incidence of septoria canker on current whips of poplar stooling in nurseries.

Clones	Intensity*	Distribution*	Incidence*
	Brooks Horticultural Station		
P. 'Brooks #6'	28	35	0.63
P. petrowskyana	48	64	1.12
	Indian Head, P.F.R.A. Tree Nursery		
P. 'FNS #44-52'	10	13	0.23
P. 'Gelrica'	6	6	0.12
P. 'Northwest'	112	116	2.78
P. 'P38 - P38'	11	15	0.26
P. tristis	13	13	0.26

* See Appendix C. A total of 50 stools in each clone were examined for cankered whips.

Table 3. Incidence* of septoria canker on hybrid poplar progeny under nursery conditions.

Clones	No. of trees	1965	1966	1967	1970
Plot MS-510 (1965) Hadashville, Manitoba (Forest Tree Nursery)					
_P_. 'berolinensis'	4	0.00	0.50	0.50	
_P_. 'Brooks #1'	5	0.00	0.00	0.25	
_P_. 'cardiniensis'	5	0.00	0.40	1.00	
_P_. _deltoides_ var. _occidentalis_	1	0.00	0.00	0.00	
_P_. 'FNS #44-52'	2	0.00	0.50	0.50	
_P_. 'Gelrica'	5	0.20	0.20	0.20	
_P_. 'Northwest'	4	0.00	0.33	0.33	
_P_. _petrowskyana_	5	0.00	0.50	0.75	
_P_. 'Saskatchewan'	5	0.25	0.50	0.50	
_P_. _tristis_	4	0.25	0.25	0.50	
_P_. 'Vernirubens'	3	1.00	1.00	1.00	
_P_. 'Volunteer'	4	0.00	0.50	0.75	
Indian Head, Saskatchewan					
_P_. 'Northwest' (1965 Plantation)					0.10

x See Appendix C

infection over several years. Healthy, juvenile trees planted in isolated areas may never get stem infections even though low levels of inoculum are present in the area. No signs of any septoria epidemic or a modest yield of ascospores of Mycosphaerella populorum Thompson on overwintered leaves occur in ten major plantations of hybrid poplar established in Saskatchewan since 1958.

The fungus S. musiva together with its overwintering state M. populorum Thompson is abundant on foliage of hybrid poplar particularly during epidemics of both leaf and stem infections of whips in a nursery. It is infrequently abundant in recently planted and natural stands of hybrid poplar as well as native balsam poplar. But it does not occur on aspen and reports of its occurrence are erroneous. The fungus overwinters vegetatively as septoria spores in well-drained, dry, sandy locations. In wet areas, moist boreal forests, or cultivated plantations, leaf mould destroys the fungus. S. musiva cannot compete with other leaf pathogens particularly Marssonima occurring on hybrid poplar and balsam poplar; or with S. populicola Pk. occurring predominantly on balsam poplar; or with saprophytes such as Cladosporium, Alternaria, Pleospora, Stagonospora, Caliciopsis, and Dendryphiopsis which abound in the thick cork of bark.

Frequently, it is too late to apply control measures when cankers become inactive, the host shows signs of decadence, loss in vigor or even death, and the pathogenic role of the fungus drops or disappears. Sanitary control measures such as pruning and burning of cankered limbs may be adequate and inexpensive in the first 3 or 4 years of establishment of a shelterbelt or a plantation. A suitable fungicidal spray program for control of septoria leaf spot and canker in the nursery stooling beds should begin not later than 10 to 15 days after leaf buds have broken and be continued at intervals of 10 to 14 days. It may begin approximately July 1 or earlier and end August 20 or 30 to effectively reduce the inoculum potential during the summer months when the shoots are growing rapidly.

GALL AND ROUGH-BARK OF POPLAR (Figure 56-63)

Bark infections by the fungus Diplodia tumefaciens (Shear) Zalasky result in localized woody swellings on trunks, branches, and twigs of trees. While infection is confined to the bark, the fungus induces the cambium to produce abnormal quantities of cork and sapwood as in woody galls. Frequently, only excessive cork will form and result in rough-bark if infection occurs in older bark. Gall and rough-bark disease may occur as individual swellings or as series of contiguous swellings. On a tree bearing one-sided infections, they face in various directions, often being associated with individual branch stubs, branch scars, and bud-brooming galls caused by mites.

Infections begin as wart-like swellings on branches and stems of juvenile trees and later on twigs or brachyblasts. These swellings enlarge into globular, concrescent galls frequently encircling the stem. Soft, spongy tissues of cork form rapidly while older cork tissues harden into crusty fissured layers characteristic of rough-bark. The galls become conspicuously large and black. Infections frequently induce swellings in the bark of trunks and main branches of mature trees and they usually result in rough-bark formation. Occasionally, the circular patches of infections do not result readily in rough-bark formation even though abundant black fructification of the fungus may occur in concentric rings.

Woody galls and rough-bark caused by D. tumefaciens occur on current season's growth as well as on mature stems. The disease is prevalent in most natural stands and in planted stands of hybrid poplar (Zalasky et al., 1965) in close proximity. Disease incidence fluctuates greatly over short distances. The persistence and the extent of the condition on main trunks and roots of most poplars make it economically important. Infections within dead branch stubs and after gall mite infestations often result in cinder-gall cankers when the cambium is killed by the activities of secondary weak pathogens.

The disease commonly occurs on all species of poplar (Zalasky, 1964) and some hybrids (Zalasky, 1965). It may be found in valleys and on hills, hillsides, or high embankments. On hybrid poplar, the oldest known infection is in a stand of 30-year-old Russian poplar at Oliver Tree Nursery. The fungus is readily distributed by water, birds, and gusty winds.

One can control the disease in hybrid poplar by planting juvenile trees away from the source of infections and by sanitation measures. Pruning and burning any infected limbs of source trees should prevent the fungus from spreading locally to nearby plantings. However, a severely infected natural stand may be clear-cut to destroy the fungus and to reduce the chances of infection in a plantation.

LITERATURE CITED

Anonymous. 1969. Hail studies (Reprint) Annual Report. Res. Counc. of Alberta, Edmonton, Canada.

Baranyay, J.A. 1964. The condition of shelterbelts in Alberta. Can. Dep. Forest., Forest Entomol. and Pathol. Lab., Calgary. Inform. Rep.

Bier, J. 1967. Septoria leaf spot and stem canker of poplar. In A.G. Davidson and R.M. Prentice, Important forest insect and diseases of mutual concern to Canada, the United States, and Mexico. North Amer. Forest. Comm., FAO. Dep. Forest. and Rural Develop.

Cayford, J.H., V. Hildahl, L.P. Nairn, and M.P.H. Wheaton. 1959. Injury to trees from winter drying and frost in Manitoba and Saskatchewan in 1958. Forest. Chron. 35: 282-290.

Cram, W.H. 1960. Performance of seventeen poplar clones in south central Saskatchewan. Forest. Chron. 36: 204-208.

Hord, H.H.V., H. Van Groenewood and C.G. Riley. 1957. Low temperature to roots of white elm. Forest. Chron. 33: 156-163.

Morgeneyer, W. 1960. Observations on frost damage and Cytospora attack in the poplar variety collection in Graupa after anomalous weather of the winters 1954-55 and 1955-56. Wiss. Abh. dtsch. Akad. Landw. Wiss. Berlin 44: 23-44.

Parker, J. 1965. Physiological diseases of trees and shrubs. Advancing Frontiers of Plant Sci. 12: 97-247.

Reek, W.A. 1958. Weather injury to trees in Manitoba. Bi-Mon. Progr. Rep. 14: 1-2.

Renick, J.H. 1969. Alberta hail studies. 1968 field program. Res. Counc. of Alberta, Edmonton, Canada.

Riley, C.G. 1953. Hail damage in forest stands. Forest. Chron. 29: 139-143.

Sakai, A., and M. Saito. 1967. Desiccation damage of forest trees in winter (11). Effect of temperature on water ascent in the stem. J. Jap. Forest. Soc. 49: 243-252.

Sorauer, P. 1914. Manual of plant diseases. Volume I Non-parasitic diseases. 3rd ed. In collaboration with Prof. Dr. G. Lindau and Dr. L. Reh, tr. by Frances Dorrance. Wilkes-Borrie, The Record Press.

Wilner, J. 1952. A study of desiccation in relation to winter injury. Sci. Agr. 32: 651-658.

Zalasky, H. 1964. The histopathology of Macrophoma tumefaciens infections in black poplar. Can. J. Bot. 42: 385-391.

Zalasky, H. 1965. Additional hosts of Diplodia tumefaciens (Shear) Zalasky (Macrophoma tumefaciens Shear). Plant Dis. Rep. 49: 50.

Zalasky, H., O.K. Fenn, and C. H. Lindquist. 1968. Reactions of poplars to infection by Septoria musiva and Diplodia tumefaciens and to injury by frost in Manitoba and Saskatchewan. Plant Dis. Rep. 52: 829-833.

APPENDIX A

Botanical and common names of poplar currently in use or under test.

Botanical Name	Common Name
P. acuminata	Lanceleaf cottonwood
P. alba var. *nivea*	Silver poplar
P. angustifolia	Narrowleaf cottonwood
P. 'AS #2'	
P. balsamifera	Balsam poplar
P. berolinensis	"Russian" poplar
P. 'BNW #4'	
P. 'Brooks #1'	Griffin poplar
P. 'Brooks #4'	
P. 'Brooks #7'	
P. 'Brooks #10'	
P. 'cardeniensis' (?)	
P. deltoides	Eastern cottonwood
P. deltoides var. *occidentalis*	Plains cottonwood
P. 'Dunlop'	
P. 'FNS #44-52'	
P. 'Gelrica'	
P. incrassata	
P. 'Italica'	Lombardy poplar
P. 'Northwest'	
P. petrowskyana	"Russian" poplar
P. 'Regenerata'	
P. 'Robusta'	
P. 'Saskatchewan'	

Botanical Name	Common Name
P. songarica	
P. '38P38'	
P. tremuloides	Trembling aspen
P. trichocarpa	Black cottonwood
P. tristis	
P. 'Tristis #1'	
P. 'Vernirubens'	
P. 'Volunteer'	
P. 'Wheeler #4'	

APPENDIX B

CAPTIONS

Fig. 1. Trunk wounds resulting from winter injury to planted cottonwood (*Populus deltoides*) in southern Manitoba. A, drying zone of unhealed frost cracks occurring in March; B, open and unhealed frost crack; C, drying zone and dead bark that is beginning to peel and fray. Photo taken in September.

Fig. 2. Winter injury to planted cottonwood in southern Manitoba. A, frost cracks with dead bark in drying zone pushed outward by a ridge of new sapwood; B, a series of frost cracks at canker stage. Sapwood production beneath prevents girdling of stem.

Fig. 3. Winter injury to trunk of balsam poplar (*P. balsamifera*) in a natural stand. North Saskatchewan River valley, Central Alberta. Trunk wounds. A, two horizontal clusters of frost cracks at various stages of healing; B, frost crack that failed to heal; C, brooming of branches from ridges of sapwood beneath the cankered bark.

Fig. 4. Winter injury to Russian poplar at Edmonton, Alberta. A, current unhealed frost crack over 3 ft long (note the beginning of a flat-faced canker in the upper region where most drying occurred); B, previous frost cracks affected by drying and cankering.

Fig. 5. Hybrid poplar FNS 44-52 in plantation. Southern Saskatchewan. Trunk canker resulting from winter injury accompanied by drying of tissue. A, frost cracks; B, drying zone affecting the bark

and sapwood; C, marginal healing tissue (mostly sapwood) occurring at mid-region where drying is reduced. It gives the canker a spearhead appearance. The healing tissue is too weak to protect the stem from complete girdling. With alternate wetting and drying, the bark sloughs away, leaving the wood permanently exposed to activity of numerous soft-rotting fungi.

Fig. 6. Winter injury in hybrid poplar of unknown origin. Shelterbelt planting in southern Manitoba, 5 years old. A, frost crack observed in March; B, a series of frost cracks inhabited by sooty moulds. Frequently, cracks in the bark of mature trees may be 10 to 20 ft long.

Fig. 7. Winter injury in cottonwood, 10 years old. Southern Manitoba. A, weakly healed frost crack; B, small frost cracks failed to heal.

Fig. 8. Winter injury in Northwest poplar in southern Saskatchewan. Plantation 8 years old. A, successive frost crack injuries and ridges of sapwood beneath the injured bark at base of trunk; B, wounds in bark caused by injuries from implements operating too close to the tree.

Fig. 9. Winter injury dating back 20 years or more. Old basal canker in 30-year-old Wheeler poplar, Mortlack, Saskatchewan. A spearhead canker with rough margins, a flat face and receding lines of marginal sapwood. A to B, dry ridge-like zones of wood; C, ridge of living sapwood acting as a wedge against the moribund layers of bark.

Fig. 10. Ten-to-12-foot canker on Northwest poplar, Winnipeg, Manitoba. Tree 15 years old. Basal canker started from winter injury when the tree was about 7 years old (A, center of canker). B, succeeding zones of sapwood varying in thickness and width indicating corresponding changes in vigor (note the absence of bark from the face of the canker); unhealed branch wounds help widen the drying zone. In weak poplar trees, it is unwise to prune branches when trees are dormant.

Fig. 11. Old winter-injury in Russian poplar at Edmonton, Alberta. A, severe cankering on main branches; B, canker resulting in dead leader. The lateral branches have taken over the role of the leader making the tree open-crowned. Tree 20 years old.

Fig. 12. Northwest poplar affected by winter injury dating back about 10 years. Winnipeg, Manitoba. Tree 15 years old. Bark in poor condition. A, pruning wounds failed to heal; B, frost cracks, dead bark being raised by ridges of sapwood; C, dead, loose bark in the basal region.

Fig. 13. Recent winter-injury in Russian poplar, Edmonton, Alberta. Tree 10 years old. A, dieback affecting the upper half of the crown and failure to form a new leader.

Fig. 14. Winter injury to Russian poplar in stooling bed. Southern Alberta nursery. A, dieback of stock; B, spindly whips; C, mouse injury to cortex. Stock declining in vigor.

Figs.15 and 16. Delayed symptoms of winter injury to 5-year-old tristis poplar at Hadashville, Manitoba. Fig. 15.A, severe defoliation and spindly shoots heavily infected with Marssonina populi late July and early August; Fig. 16. Winter injury to roots, black patches A, observed in early spring. Trees died in large numbers in June and July. Out of 100 trees, there were few remaining.

Fig. 17. Old winter-injury to Russian poplar at Edmonton, Alberta. Leader lost as a result of earlier winter-injury. A, canker; B, suckers. Tree 20 years old.

Figs. 18 to 20 Cultivation damage to roots of hybrid poplar FNS 44-52 in 5-year-old plantation. Northern Saskatchewan. Fig. 18A, surface main roots severed by discing; B, multilation; Fig. 19A, surface main root dislodged from original position by cultivator; B, poorly healed frost cracks resulting in permanent injury to bark; Fig. 20A, main root dislodged and mutilated.

Fig. 21. Hybrid poplar FNS 44-52 in 8-year-old plantation. Southern Saskatchewan. Partially excavated to show damage to roots. A, surface main root pulled out and exposed to drying; B, main root severed by deep discing or rototilling; C, surface root scraped along the top; D, 18-inch square, E, 12-inch ruler; F, poor condition of bark resulting from winter injury and root damage. This is typical of many young trees in plantations.

Fig. 22. Same tree as in Fig. 21. Winter injury and drying of bark in the lower crown of main stem. First appears as a discolored water-soaked area, A, collapsed bark; B, branch dieback. Several acres of trees died in this plantation. The remainder of the trees in the background were too weak to survive another winter. All trees were in semi-defoliated state late July and early August.

Fig. 23. Shelterbelt planting 8 years old. Unspecified natural hybrid of cottonwood near Winnipeg, Manitoba. All main roots on both sides of the row were cut off at the trunk by deep discing. A, dense suckering from base of trunk and around cankers. B, all trees were severely defoliated in late July and early August. The prevalence of spindly current year's shoots, small leaves and leaf scorch indicates a sharp decline in vigor of all trees.

Fig. 24. Shelterbelt established 5 years ago in southern Manitoba. Hybrid poplar of unknown origin. Type of cultivation: close rototilling around trees. A, massive suckering at base of tree; B, suckering at the trunk, lower crown; C, trunk cankers. Most trees suckered in this shelterbelt.

Fig. 25. Fire-scorched bark of juvenile aspen after a spring ground fire near Edmonton, Alberta. A, discoloration in bark a few days after the injury by instantaneous heat; B, amber gum-deposit having oozed from the scorched bark; C, grass flash-burnt April 22, 1970.

Figs. 26 and 27 Fire-scorched bark of juvenile balsam poplar near Edmonton, Alberta. A, scorched areas of the bark; B, fire scar from previous year; C, a thick film of dark gummy material on the injured bark; D, injured trees in the background; E, leaf litter, grass, and herbaceous burn in early spring, April 28, 1970.

Figs. 28 to 30 Fire-charred bark of 30-year-old balsam poplar at same site as juvenile trees shown in Figs. 26 and 27. A, charred pockmarks from current burn; B, flash-burnt grass and litter; C, scarred wood and bark from two previous burns.

Fig. 31. Fire-scorched aspen in same locality as material in Figs. 26 and 27. A, C. chrysosperma on branch and main stem 6 weeks after injury.

Fig. 32. Pole-sized stand of aspen two years after a ground fire and understory fire near Edmonton. A, vertical splitting of bark; B, long strips of bark peeling. Courtesy of Mr. D. Stelfox, Crops Clinic, Alberta Department of Agriculture.

Fig. 33. Fire-scarred trees of pole-sized aspen near Edmonton. A, typical fire scar cankers; B, peeling bark.

Fig. 34. Juvenile aspen 10 weeks after injury from flash fire near Edmonton. A, vertical splitting of injured upper layers of bark; B, C. chrysosperma fructifications on fire-scorched branch.

Fig. 35. Fire-scorched balsam poplar near Edmonton. A, basal girdling of stem; B, upper stem alive 3 months after injury but the tree is not expected to survive.

Figs. 36 to 41 Fire-injured shelterbelt of Russian poplar near Edmonton, Alberta.

Fig. 36. A, vertical splitting of heat-injured bark about 6 ft above ground in trees shown in Figs. 36 and 37.

Fig. 37. Pockmarks. A, bark charred in small eruptive spots where hot gases and resins escaped. B, typical concentric zones around eruptive spots; C, vertical and horizontal splitting of bark. The underlying sapwood would be dead.

Fig. 38. Injury to bark in basal part of the trunk. A, area of basal fire scar in bark and wood; B, vertical splitting in bark; C, charred pockmarks above the fire scar.

Fig. 39. Live suckers on opposite side of injured trunk. A, fire scar; B, peeling bark; C, suckers.

Fig. 40. Severely damaged trees in foreground and moderately damaged trees in background indicate changes in intensity of fire presumably because of changes in direction and velocity of wind. A, dead trees with varying degrees of charring of bark and wood; B, branch suckers in survived trees.

Fig. 41. General photo to show understory that acted as a fuel in the ground fire. A, caragana, Manitoba maple and green ash with the stubble field in the background and grass in the foreground providing ideal conditions for flash ground-fires; B, dead tops, C, branch suckering in surviving trees; D, dead trees; E, charred remains of burnt trees.

Fig. 42. Fire-scorch injury in regeneration aspen. North central Boreal forest area in Saskatchewan. A, collapsed and drying area of bark.

Fig. 43. Older fire-scorch injury to regeneration aspen near Candle Lake, Saskatchewan. A, large area of scorched bark. Nectria galligena and Cytospora chrysosperma found fructifying in dry, dead bark; B, healing tissue on back side. The fungi are confined to dead bark and wood only.

Fig. 44. Fire-scorch injury to regeneration aspen near Candle Lake, Saskatchewan. A, Nectria galligena fructifications in abundance on dead zone of the bark; B, lack of healing tissue around the margin. Drying zone of bark extended beyond the original canker.

Fig. 45 Fire-scorched bark in pole-sized aspen near Edmonton, Alberta. A, older bark lifted, cracked and overgrown with sooty moulds.

Fig. 46. Hail injury to mature Russian poplar in shelterbelt near Edmonton, Alberta. A, severely damaged bark as a result of a July hail storm. All injuries healed. The black discoloration on hail marks result from drying bruised cortex being colonized by various saprophytic fungi, the most common being Cladosporium, Alternaria, and Phoma.

Figs. 47 and 48. Severe hail injury during July to 5-year-old Griffin poplar in a nursery near Edmonton, Alberta. A, all injuries healed except for B, where the bark was stripped from the upper side of the branch. The bare wood eventually dries and the narrow strip of living tissue at the back side serves as a temporary bridge before the branch dies.

Figs. 49 and 50. Saperda injury in hybrid cottonwood in a shelterbelt near Winnipeg, Manitoba. A, unusual cankers resulting from Saperda infestations and galls in the upper crown, many of which fail to heal; B, suckers on trunk.

Fig. 51. Stooling stock of Russian poplar in a Southern Alberta nursery. A, mouse injury to cortex and near girdling of main stem at snow level. Fortunately, the cambium is undamaged. Most injuries usually heal reasonably well but it reduces the productivity of the stock; B, previous year's spindly whips; C, dieback indicating that the stock is declining in vigor.

Fig. 52. Septoria canker in Brooks #6 poplar. Nursery stooling beds in southern Alberta. A, canker nearly girdling the tree is 2 years old; B, thin sapwood on the back side is alive and gives temporary support to the stem prior to breakage by wind. Note, there

is no new sapwood formed beneath the dead bark in canker A, since the fungus invades and kills all living tissues of the bark and sapwood. This feature makes septoria canker distinctive from other cankers described earlier.

Fig. 53. Three-month-old seedling of balsam poplar in Manitoba artificially infected with Septoria musiva. A, collapsed dead central part of the canker discolored ash-gray; B, pycnidia of the fungus arranged in an oval circle; C, dark zone of discoloration on the outside of the canker shows checked bark where a ridge of living sapwood is being formed. When the stem is girdled and the dead tissues in the canker dry, the fungus ceases to be an effective pathogen. Simple pruning ensures that buds in the lower living portion will rejuvenate the young plant.

Figs. 54 and 55. Three septoria cankers on main stems of natural hybrid cottonwood in a southern Alberta nursery. A, cankers 2 years old but shorter and smaller than in Fig. 35. They generally heal if the poplar is growing vigorously.

Figs. 56 and 57. Cinder-gall and rough-bark caused by Diplodia tumefaciens in naturally infected pole-sized aspen occurring along the north Saskatchewan River in central Alberta. Prominent swellings; A, in back of main stem date back when regeneration-size trees were infected and stem galls were formed. Only a horizontal ring remains to indicate the position of the gall. Stems are infected from the base up into the crown.

Fig. 58. Aspen in southern Manitoba. D. tumefaciens infection. A, horizontal lines showing remnant of an earlier stem gall. Note

deep-fissured bark B in the affected zone.

Fig. 59. Cinder-gall and rough-bark in pole-sized aspen at Riding Mountain National Park, Manitoba. Main stem distorted with swellings A, rough-bark B, and cinder-gall C. Certain clones of aspen are believed to be more susceptible than others.

Fig. 60. Pole-sized balsam poplar recently infected with D. tumefaciens. Whitemouth River, southern Manitoba. Note circular horizontal patches A, with zone lines of fungus fruiting bodies B and rough-bark C.

Fig. 61. D. tumefaciens infection on mature balsam poplar in stands near Edmonton, Alberta, North Saskatchewan River valley. Note horizontal zones of infection A.

Fig. 62. Mature balsam poplar and Fig. 63 planted mature Russian poplar infected with D. tumefaciens near Edmonton, Alberta. Both stands are close together. Note galls A, swellings B on branches and C on main stem Fig. 62. Soft spongy type of galls A are produced on the main stem of Russian poplar Fig. 63. Succulent tumerous tissue is subject to infestation and feeding by insect larvae and to injury by severe winter conditions.

APPENDIX C

The equation for computation of disease incidence (IM) is based on intensity (II) and distribution (ID) $IM = \frac{\Sigma(II \times p) + \Sigma(ID \times p)}{2 \times P}$, where p is the number of diseased plants and P is the number of plants examined.

Intensity ratings for winter injury

0 - no frost damage; 1 - leaves frosted; 2 - leaves frosted and 1 to 6" of tip dieback; 3 - leaves frosted and 7 to 12" of tip dieback; 4 - leaves frosted and 13 to 24" of stem dieback; 5 - leaves frosted and 25 to 48" of stem dieback.

Distribution ratings for winter injury

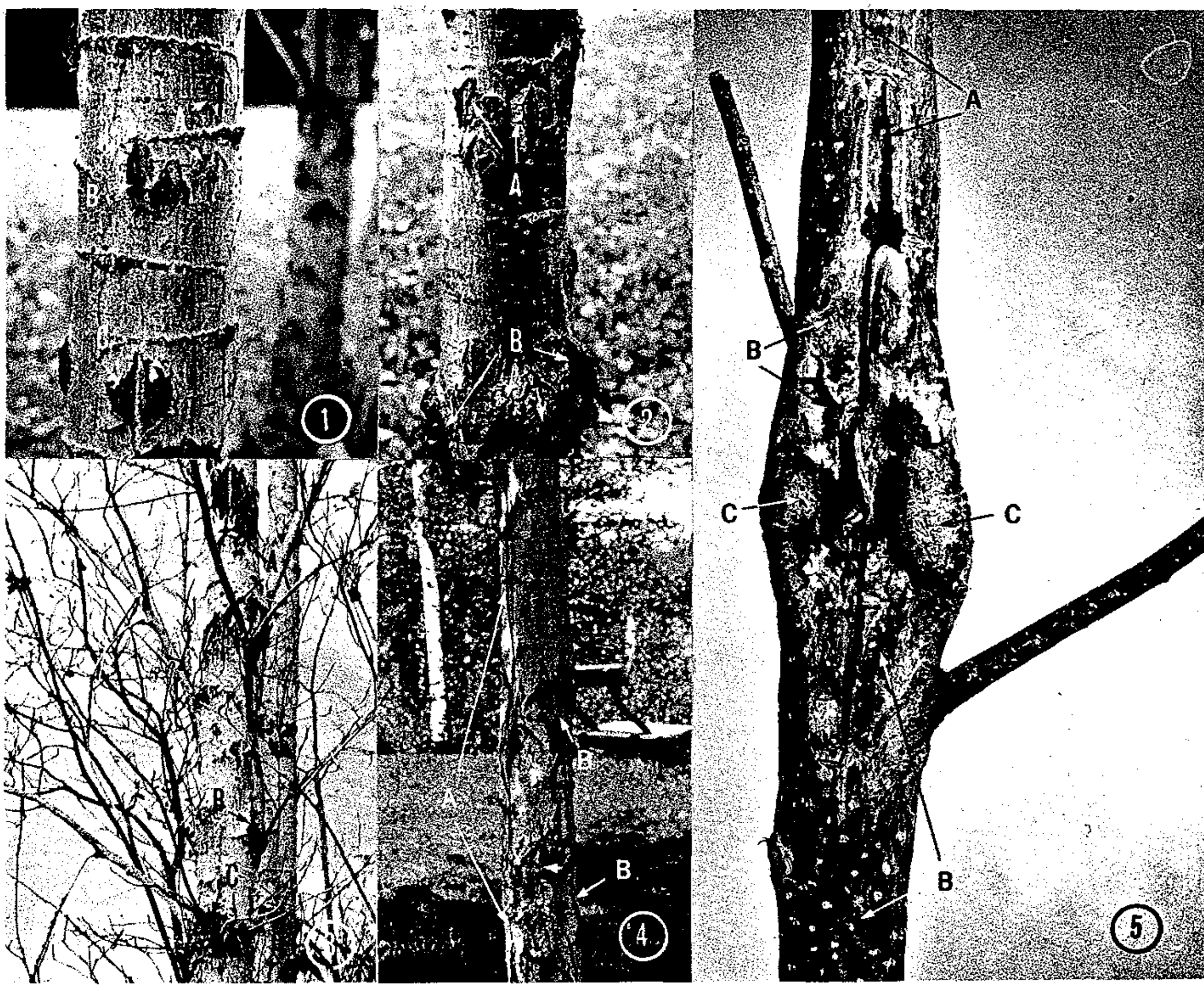
0 - no twig dieback or root injury; 1 - leaves frosted; 2 - leaves frosted and 1 to 6" of tip dieback; 3 - leaves frosted and 7 to 12" of tip dieback; 4 - root injury; 5 - leaves frosted and 13 to 24" of stem dieback; 6 - root injury in addition to previous rating; 7 - leaves frosted, 25 to 48" of stem dieback; 8 - root injury in addition to previous rating.

Intensity ratings for septoria canker

0 - no cankers; 1 - one to two cankers; 2 - three cankers; 3 - four to five cankers; 4 - five cankers.

Distribution ratings for septoria canker

0 - no cankers; 1 - one canker; 2 - two cankers; 3 - three cankers; 4 - four cankers; 5 - five cankers; 6 - more than five cankers.



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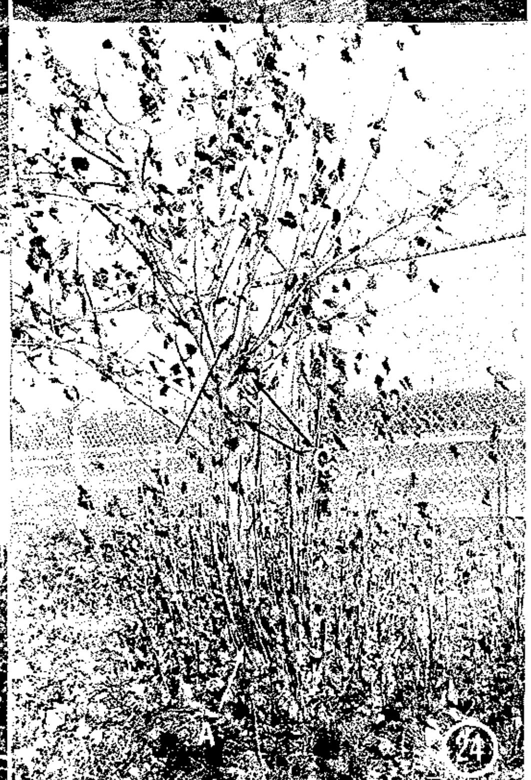
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