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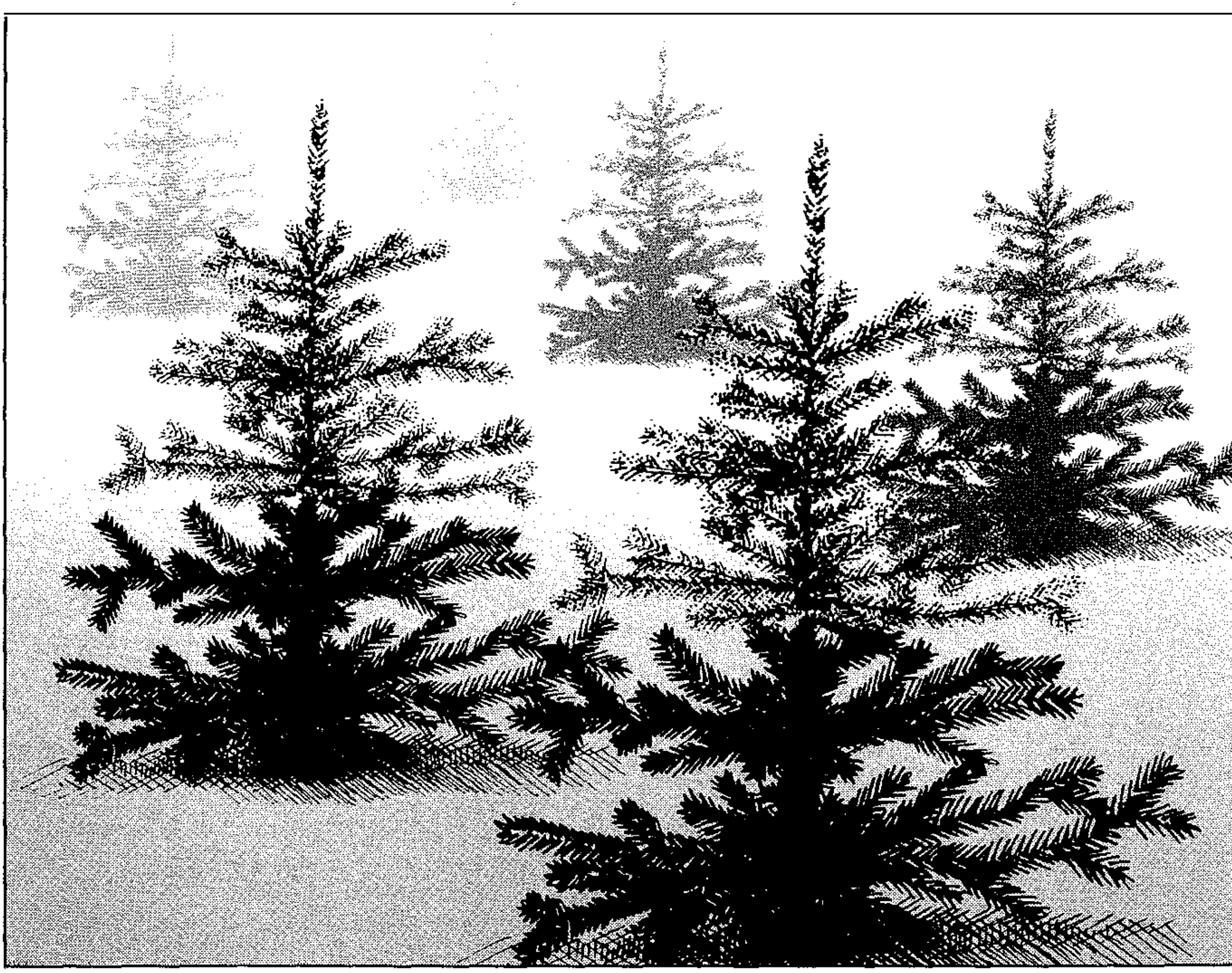
Y. Hiratsuka and H. Zalasky

Northwest Region • Information Report NOR-X-331



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ABSTRACT

Frost and other climate-related damage of forest trees in the Canadian prairie provinces are described in terms of their cause and damage, symptoms and diagnosis, and prevention and control. Types of frost damage, winter desiccation, red belt, needle droop of red pine, drought damage, snow and ice glaze damage as well as wind, hail and lightning damage are addressed. Photographs are used to illustrate symptoms and aid in the diagnosis of these kinds of damage.

RÉSUMÉ

Les auteurs décrivent les dommages attribuables au gel et à d'autres facteurs climatiques infligés aux arbres forestiers dans les provinces canadiennes des Prairies; ils font état des causes et des dégâts, des symptômes et des méthodes de diagnostic ainsi que des mesures de prévention et de protection. Ils abordent les types de dégâts dus au gel, la dessiccation hivernale, le rougissement, la courbure des aiguilles de pins rouges, ainsi que les dégâts dus à la sécheresse, à la neige et au verglas, au vent, à la grêle et à la foudre. Ce rapport présente des photographies pour illustrer les symptômes et faciliter l'identification du type de dégâts.

ACKNOWLEDGMENTS

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FIGURES

Note

The exclusion of certain manufactured products does not necessarily imply disapproval nor does the mention of other products necessarily imply endorsement by Forestry Canada.

Climate-related damage and fire, together with damage caused by biotic agents such as insects and microorganisms, have a significant impact on stand structure, species composition, stand value, crown and trunk shape, and biomass production of forest stands (Grier 1988; Zalasky 1976, 1986). Temperatures below freezing, alternation of freezing and melting, and accumulation of ice glaze and snow on trees are common causes of climate-related damage to trees. Climatic conditions are the most common and probably the most important causes of tree damage and mortality in the Canadian prairie provinces because of the subarctic continental climate (Carder 1965).

Identification of climate-related damages of forest trees is often difficult because of the absence of visible signs of the cause of the damage (Fig. 1). The occurrence of many subsequent events such as natural pruning of dead shoots and twigs camouflaged by new growth, weathering of dead tissues, scaling, and growth of secondary microorganisms also hinders the correct identification of these types of damage. Some microorganisms that colonize frost-killed tissues can easily be mistaken for the primary causal agents. For example, many of the previous reports of Cytospora canker and Nectria canker in the prairie provinces and other parts of Canada are likely frost-damaged parts of the tree quickly colonized by these fungi.

There are two main types of frost injuries. One is spring or late-frost injury to current succulent shoots, which occurs during sudden unusually cold temperatures in the spring. The other type of damage occurs during the winter and can affect trees of all ages, resulting in canker, dieback, and growth deformities. Frost injuries tend to develop when unusually warm temperatures alternate with cold temperatures over a short period of time. These injuries most frequently affect trees with juvenile tissues; trees with unhealed wounds caused by glaze, hail, wind, or snow; and weakened transplanted trees.

Red belt, a particular winter desiccation damage thought to be caused by a combination of climatological conditions that cause sudden thawing of sap during the winter, occurs mainly on the eastern slopes of the Rocky Mountains. It is considered to be related to the drastic rise of the air temperature during the winter, which is called the chinook phenomenon (Henson 1952; Robins and Susut 1974).

The earliest records of frost damage in the prairie provinces are from the turn of the century (Saunders 1904; Ross 1910), when damage to introduced tree species in nurseries and rural areas was documented. Other documented cases of climate-related damage in the prairie provinces include frost damage (Hord et al. 1957; Cayford et al. 1959; Zalasky 1975, 1976, 1977, 1980, 1986), glaze damage (Cayford and Haig 1961), red belt (Henson 1952; Robins and Susut 1974), and hail damage (Riley 1953; Laut and Elliott 1966). In recent years, it has been suggested that certain species or strains of surface microorganisms (epiphytes) such as bacteria and yeasts are important frost damage initiators or enhancing agents such as ice-nucleating agents (INA) (Zalasky 1985).

This publication contains general descriptions, diagnosis, and suggestions for prevention and control of major frost and other climate-related injuries of forest trees that commonly occur in the Canadian prairie provinces. Although most of the types of damage described in this report cannot be predicted or controlled, accurate identification and understanding of the nature of climate-related damage of trees are important in making reasonable forest management decisions.

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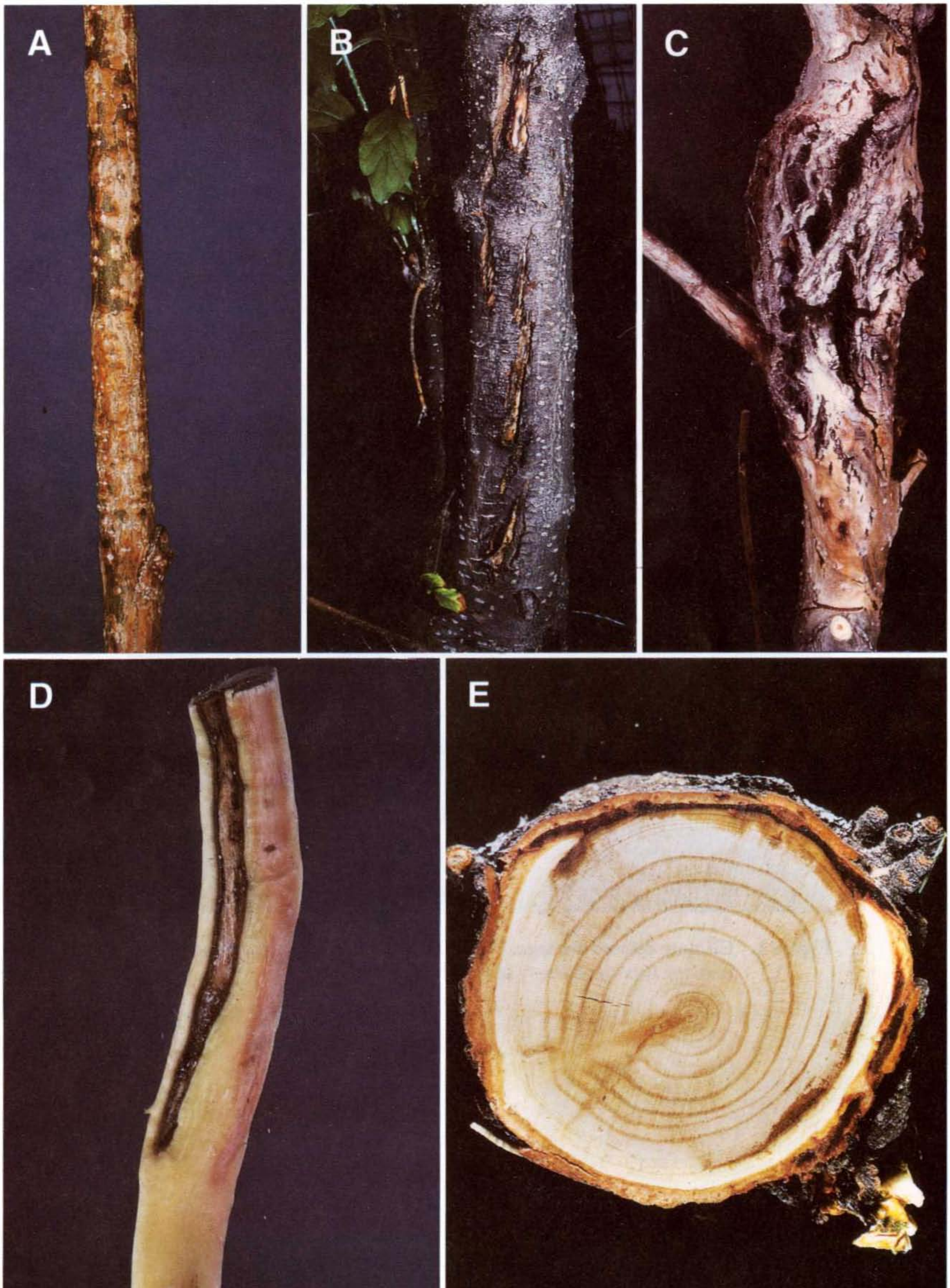
Figure 1. Climate-related damage. The scars on this branch were caused by hail damage (photo courtesy of H. Ono).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Cause and Damage

Frost damage is caused by ice formation in plant tissues. Sakai and Larcher (1987) classified freezing injuries into four types based on the location of the ice formation: intracellular freezing, extracellular freezing, intratissue freezing, and extraorganismal freezing. The degree of frost resistance changes with the developmental stages and ages of the tissue as well as the time of year. Generally, tissues are much more resistant to freezing during the late fall and winter than in the spring to early fall (Sakai and Larcher 1987; DeHayes et al. 1990). Degrees of frost tolerance also differ depending on the characteristics of the tissues (Larcher 1975). Furthermore, degrees of frost hardiness at certain times of the year vary between tree species. For example, Christersson et al. (1987) found in Sweden that summer frost hardiness between *Picea abies* (L.) Karst. and *Pinus sylvestris* L. was significantly different; they were then able to explain why spruce seedlings on many summer frost areas were severely damaged, whereas pine seedlings survived without visible injury.

Symptoms and Diagnosis

Stem damage

Three kinds of frost damage occur on stems. They are scabby bark, cracks, and cankers. Scabby bark (Fig. 2A) is a condition where the bark discolors and eventually becomes scaly as callus tissues form beneath the scabby layer. Thin bark may develop cracks (Fig. 2B) or cankers (Fig. 2C). Sunscald or frost cracks often occur on the sides of trees exposed directly, or indirectly by reflection, to the sun where the fluctuation of temperature is greatest. The cracks may remain open if the bark is dead in the damaged area and then develop into cankers, or they may be closed by new tissues from the adjacent living bark. Callus and abnormal bark develop at the margin of the canker and gradually close the wound (Fig. 2D). Small cankers require less time as well as less callus and woody tissues to close the wounds than do large cankers. Frost damaged trunks of trees may show cankers in the inner layers of woody tissues (Fig. 2E). The canker may be bridged by burls and ridges, which are often called frost ribs, consisting of many successive layers of callus and woody tissues developed at the outer margin of the wound. The bridging of a canker may take several years.

Cambium mortality caused by frost damage can be diagnosed by examining the cambium layer for dark brown discoloration (Figs. 3A, B). This can be done most effectively by cutting the area between dead and live stem zones. It is important and sometimes difficult to distinguish between frost damage and diseases caused by fungi and other microorganisms, especially when frost damage has occurred and damaged tissues have been subsequently colonized by fungi. Many so-called canker diseases such as Cytospora canker, Nectria canker, and Tympanis canker are likely winter-frost-killed tissues colonized by these secondary fungi, although some of these fungi may prove to be mildly pathogenic with the ability to invade and kill adjoining healthy tissues. Furthermore, some of the other canker diseases such as Hypoxylon canker, Scleroderris canker, and Lachnellula canker may also be mediated or enhanced by various physiological stresses including frost damage.

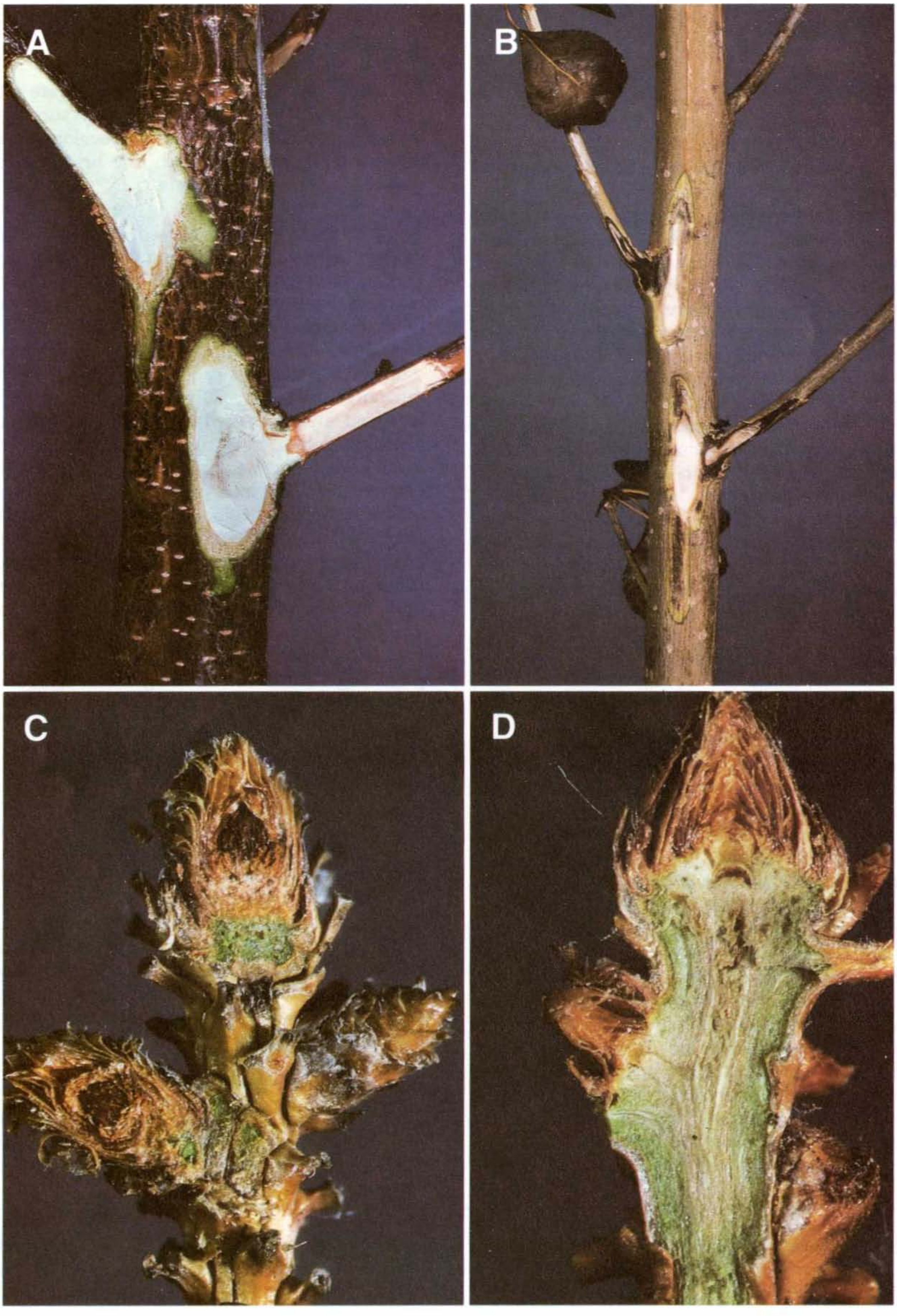
Bud damage

Three kinds of winter-frost damage occur on buds, especially on epicormic buds. They are central tissue mortality, reduced bud viability, and rosetting. As a result of terminal bud damage, trees often produce forking stems or multiple-leader development. Frost damage to buds can be confirmed by cutting through the bud and examining the condition. Damaged buds are usually discolored (Figs. 3C, D) or green but appear water soaked. Frost-damaged buds can be confused with some insect damages or bud-infecting fungi such as *Chrysomyxa woroninii* Tranz., but the latter can be identified with the presence of causal organisms in the buds.

Leaf and needle damage

In deciduous species, leaves are usually shed after an early frost; however, leaves of trees producing late-season shoots will freeze in October, turn

Figure 2. Symptoms of frost damage. A. Scabby bark on aspen. **B.** Frost cracks on lilac. **C.** Frost canker on Russian poplar. **D.** Healing old-frost canker. **E.** Previous frost damages (black layers) healing over.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brown, and shed tardily after freeze-up. In most conifers, the needles stay alive on the trees for several years and are, therefore, subjected to low temperature damage. The current year's needles, however, are most vulnerable (DeHayes et al. 1990). Affected needles discolor and defoliation occurs in the spring.

Root collar damage

Two types of frost damage occur at the root collar: cankers and girdling. Cankers may extend into the trunk. Established trees can survive the cankers by producing new bark and wood over the wound. Complete girdling of small trees, however, kills the tree roots and root collar. Containerized trees and nursery-grown trees are more susceptible to girdling damage at the root collar than naturally regenerated seedlings. This girdling damage is mainly caused by drastic temperature fluctuations at the basal area of trees, especially on exposed trees, which are subjected to direct and reflected sun light in the day time combined with low night temperatures at the ground level (Sakai and Larcher 1987).

Prevention and control

No direct control measure is available for frost damage but preventive measures, such as proper planting and care, planting of winter-hardy tree species in high-hazard areas, or avoiding unnecessary exposure of overwintering nursery stock to adverse weather conditions, can reduce damage in certain situations. Frost damage often occurs on newly planted trees. The best way to avoid damage is to plant trees in the spring, in soils with good drainage and to encourage vigorous growth so that the trees will be well established at the end of the growing season. Over the following 3–4 years, pruning the lower limbs of established hardwood trees is recommended to raise the crown and to promote a gradual increase in crown density without loss of the leader. Vigorous growth brought about by fertilizer application not only reduces the probability of winter damage but also speeds maturation of buds and wood in late summer; however, fertilizing with nitrogen later than mid-July may encourage continued growth and prevent hardening thus increasing the chance of frost injury. Fall-planted trees should be watered to the soil's full water-holding capacity before freeze-up. Once frost damage has occurred on stems resulting in formation of stem wounds, cracks, and cankers, no treatment is necessary or effective. The wounds exude their own protective resin-like substance, and the burls and ribs that form later strengthen the tree trunk. Dead branches or leaders caused by dieback may be pruned at any time on small trees, but, as a safety precaution, they should be removed as soon as possible from large trees. In long-term planning, frost damage in plantations can be avoided by evaluating the frost hardiness of common tree species (Christersson et al. 1987) and selecting frost-hardy provenances of tree species for regeneration.

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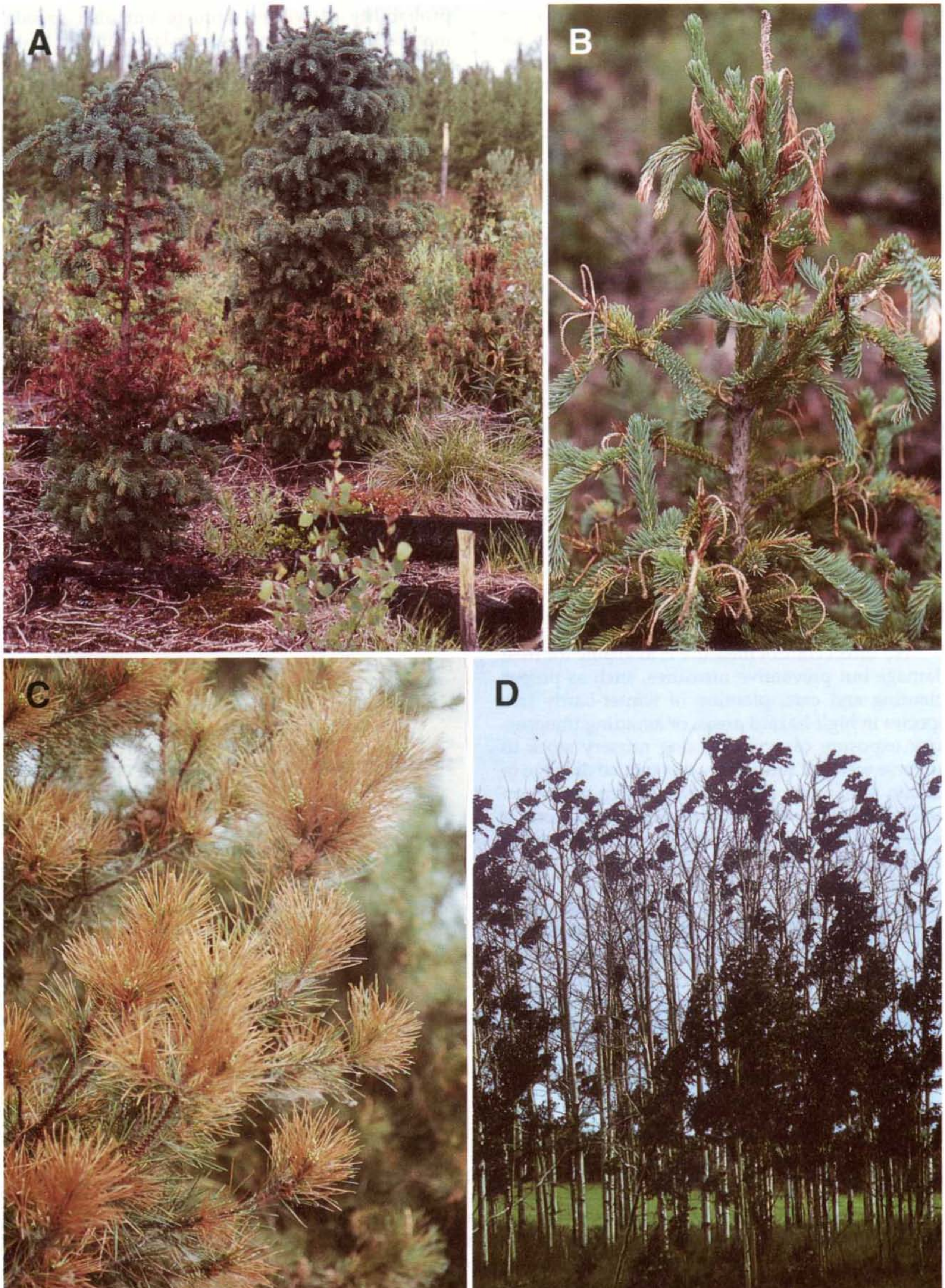
Figure 3. Mortality caused by frost damage. A. Cambium mortality (dark cambium layer). **B.** Branch dieback to the main stem due to frost damage. **C.** Cut out view of buds showing frost-killed young-developing buds. **D.** Cut out view of buds showing frost-killed young-undeveloped bud primordia.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Cause and Damage

Spring frost damage occurs in the spring when the temperature drops below freezing after new leaves or needles have already developed but are still young and succulent. When the damage occurs late in the spring or in early summer, usually only the young and succulent leaves are damaged and the mature, hardened foliage remain unharmed (Figs. 4A, B, C). The damage can be extensive in young exposed stands, but usually trees produce new shoots and recover. Repeated spring frost damage in successive years often results in deformed trees.

Symptoms and Diagnosis

Symptoms of spring frost damage are wilting, discoloration, and dropping of current year's foliage. Broad-leaf trees such as aspen will flush again after the spring frost damage but produce foliage that is patchy in appearance (Fig. 4D) because they do not reflush uniformly. Sometimes new shoots of spruce damaged by spring frost (Fig. 4B) can be confused with small shoot-tip swellings caused by infection of Cooley spruce gall adelgid (*Adelges cooleyi* [Gillette]); however, stems of shoots infected by Cooley spruce gall adelgid are swollen, while stems of shoots killed by spring frost are not. Shoot damage of spruce and pine caused by terminal weevils (*Pissodes* spp.) also can be confused with spring frost damage.

Prevention and Control

Spring frost damage often affects young exposed trees. Covering the nursery beds and valuable ornamentals when frost warnings are issued in spring will help prevent spring frost damage in amenity trees and nursery seedlings.

Figure 4. Spring frost damage. A. New growth mortality by spring frost at various heights on small trees. **B.** Typical drooping symptoms. **C.** Previous year's needles of lodgepole pine killed by spring frost. **D.** Clumping of aspen leaves caused by spring frost damage followed by second flushing.

Cause and Damage

Death of whole trees or various degrees of die-back damage occur during the winter on coniferous trees as a result of winter desiccation. The damage is also known as frost drought (Christersson et al. 1987; Sakai and Larcher 1987). This kind of damage usually occurs when the aboveground or above-snowline parts of trees are exposed to warm dry air and sun, which cause excessive transpiration, while the ground is still frozen. Often the snow-cover height at the time of damage is visible on affected trees (Figs. 5A, B). Needles under the snow cover are protected from damage because of a lower rate of transpiration. Red-belt damage, which will be discussed in the next section, is another example of winter drying damage. Two types of winter desiccation damage can be distinguished: chronic and acute (Larcher 1985). Chronic winter desiccation develops slowly due to gradual water loss by transpiration during the 3- to 4-month period in winter when no water is available from the roots because of soil frost. Acute winter desiccation damage arises from a break down of water balance, and symptoms can appear within a few days. This happens when unusually warm and dry weather conditions occur when the ground is still frozen.

Symptoms and Diagnosis

The symptoms of winter desiccation damage are discoloration of foliage of whole or parts of trees, and die back of trees. Trees damaged by winter desiccation can be confused easily with damages caused by Armillaria root rot or root collar weevil because of similar reddish discoloration. On trees affected by winter desiccation, most of the time the basal portion of the trees are still green while trees affected by Armillaria root rot or root collar weevil discolor completely and show no snow line delineation.

Prevention and Control

Protection from exposure to wind and sun during the winter may reduce the chance of winter desiccation damage. Covering planted seedlings with straw or snow (snow trapping) may prevent winter desiccation damage in high-value planted-tree seedlings in exposed sites.

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Figure 5. Winter desiccation. A. Damage to lodgepole pine showing snow-line delineation. **B.** Damage to white spruce showing snow-line delineation.


A
B

Cause and Damage

Red belt is a type of winter desiccation damage. It is discussed separately from the winter desiccation in the previous section because its symptoms and occurrence differ from other types of winter desiccation. A drastic rise in the air temperature during the winter caused by warm chinook wind conditions while the ground is still frozen is believed to be responsible for red belt (Melrose 1919; Henson 1952; MacHattie 1963; Robins and Susut 1974). Red belt occurs mainly in the upper foothills of the eastern slopes of the Rocky Mountains in western Canada. At certain elevations, the damage may occur as frequently as 20 times over a 100-year rotation of conifer species and may affect stands of all ages (Bella and Navratil 1987). Although mortality is rare, very severe red-belt damage or repeated incidences of the damage could kill significant numbers of trees.

Symptoms and Diagnosis

Symptoms of red belt first appear in early spring as reddish-brown discolored patches covering areas of different shapes and sizes. On wide slopes, the damage often appears as horizontal, well-defined bands (Fig. 6A), thus the name red belt. Needles and buds of an entire tree can be killed (Fig. 6B), but generally buds are not killed and the affected trees recover within a few years.

Extensive red-belt damage is easily recognized except when it is restricted to small-scale damage at the top of mountain ridges or edges of forest stands where it can be mistaken for damage caused by mountain pine beetle or drought.

Prevention and Control

There are no control or preventive measures available for red-belt damage. It is recommended that if red-belt damage occurs in large areas and a significant amount of mortality follows, all merchantable timber should be salvaged before decay occurs. Salvage cutting may help reduce the fire hazard danger of large amounts of dead and dry timber.

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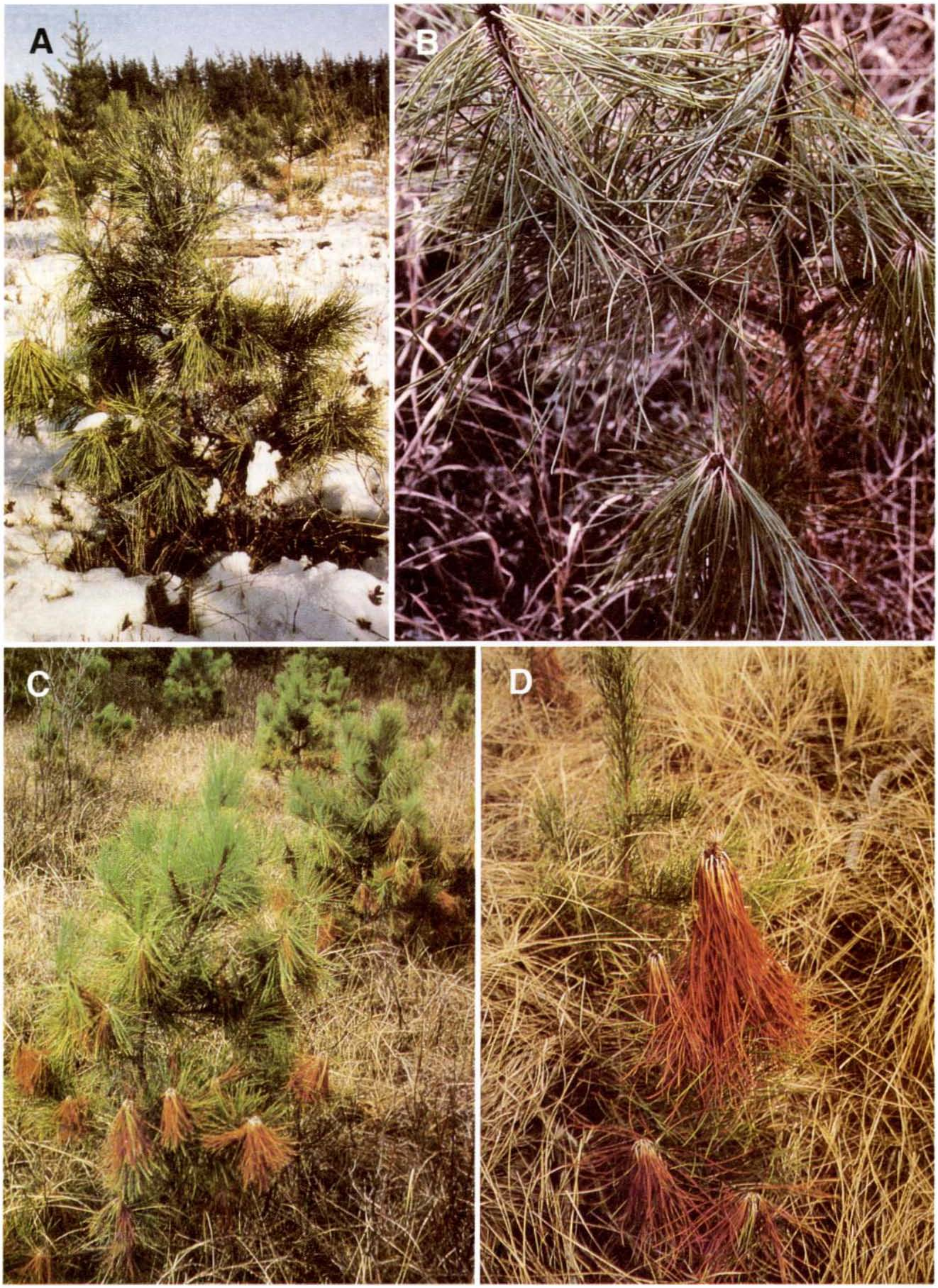
Figure 6. Red belt. A. Red belt on a mountain side. **B.** Mortality of lodgepole pine after repeated red belt incidences.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Cause and Damage

The phenomenon of needle droop typically affects red pine (*Pinus resinosa* Ait.) in Minnesota, Wisconsin, Ontario, and Manitoba (Davis et al. 1939; Patton and Riker 1954; Hall, Biggs, and MacLeod 1976; Hall, Czerwinski, MacLeod, and Jansons 1983; Plexman 1982), especially planted stock. Needle droop is caused by abnormal water flow to trees (Patton and Riker 1954). If sudden and excessive rapid transpiration occurs when soil has limited moisture supply, an absorption lag follows. Succulent tissue in the needle base collapses and causes the needles to droop. Significant numbers of planted red pine seedlings can be killed or deformed by needle droop depending on the climatic and soil conditions.

Symptoms and Diagnosis

Abnormal drooping and dying of the current season's needles are typical symptoms. Current season's needles appear sharply bent downward. Drooping occurs when the needles are still green (Figs. 7A, B). Later, the needles die and gradually turn reddish brown (Figs. 7C, D); most of them remain attached to the stem well into the next summer. Depending on the timing of the occurrence and the maturity of the needles, either the top parts of the shoots (Figs. 7A, C) or the lower parts of the trees (Figs. 7B, D) may be affected.

Needle droop can be confused with a needle blight that is caused by gall midge larvae feeding at the needle base. Symptoms of needle blight are somewhat similar to needle droop, but usually with needle blight scattered needles in a shoot are affected and evidence of insect feeding can be found.

Prevention and Control

No preventive or control measures are available for needle droop damage.

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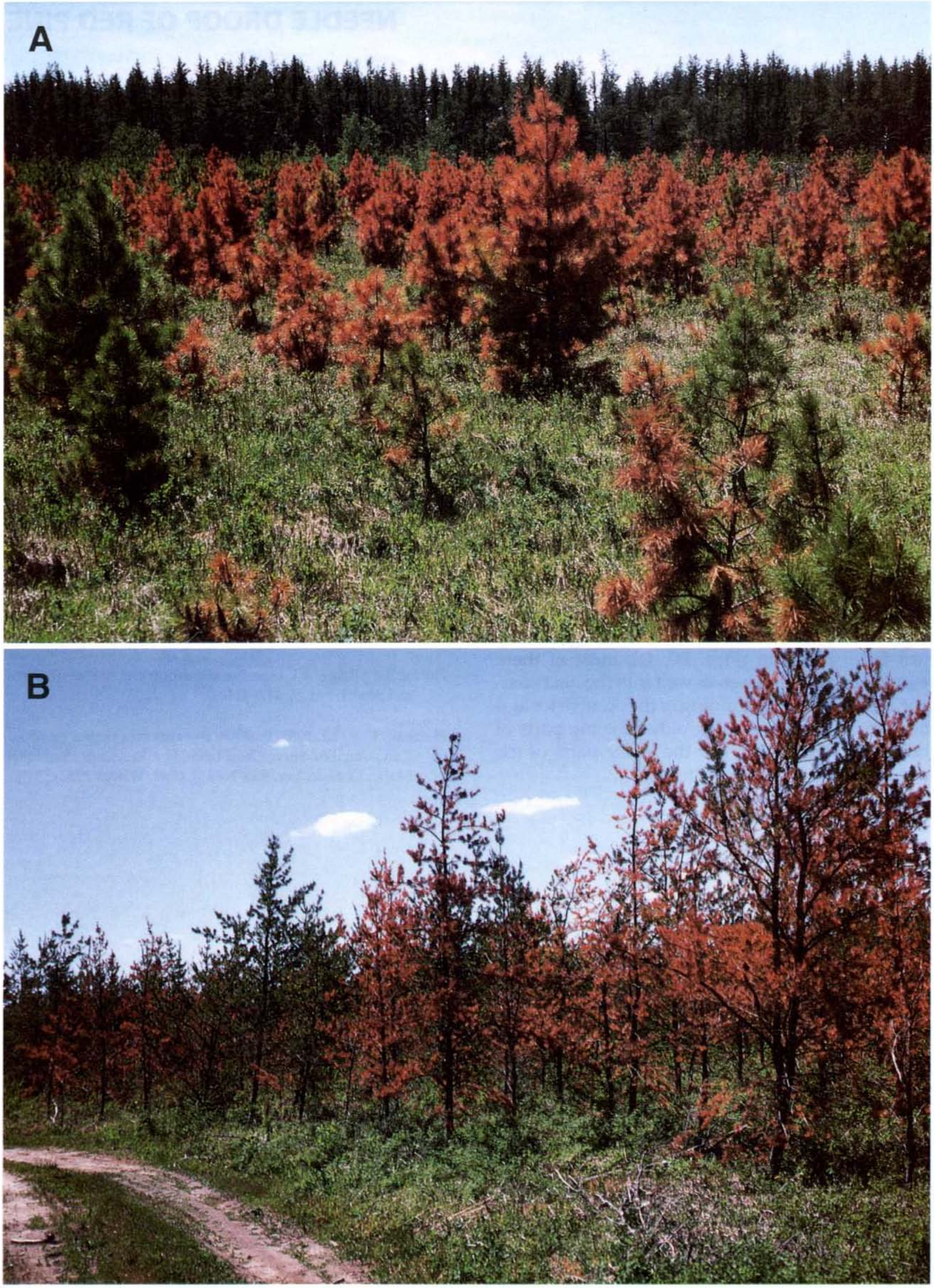
Figure 7. Needle droop of red pine. A. Needle droop on the bottom half of planted red pine. **B.** Typical needle droop symptoms. **C.** Discolored needles several months after the damage. **D.** Close-up of discolored needles.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Cause and Damage

If very dry conditions prevailed for several growing seasons, trees in a wide area may suddenly show foliage discoloration symptoms. Striking mortality of red pines in many plantations in the Bélair and Sandilands areas of Manitoba from 1985 to 1989 are believed to be caused by drought conditions that existed for several years previous to the damage. Drought damage and winter desiccation should be differentiated. Drought damage is due to a lack of adequate moisture in the soil, whereas winter desiccation occurs when moisture in the soil is temporarily unavailable because of frozen ground even if moisture is present in the soil.

Symptoms and Diagnosis

Large areas of forests can be affected by drought, and in severe cases extensive mortality occurs. Red pine and jack pine needles turn reddish brown (Figs. 8A, B). Drought damage is often difficult to diagnose because the symptoms are similar to those caused by many other insects and diseases such as Armillaria root rot, Scleroderris canker, and root collar weevil. Drought stressed trees are predisposed to the attacks of many diseases and insects. For several years after severe drought damage, various degrees of dieback and mortality of trees continue even though the drought conditions disappear.

Prevention and Control

Planting drought resistant tree species in high-risk areas should be considered to minimize drought damage.

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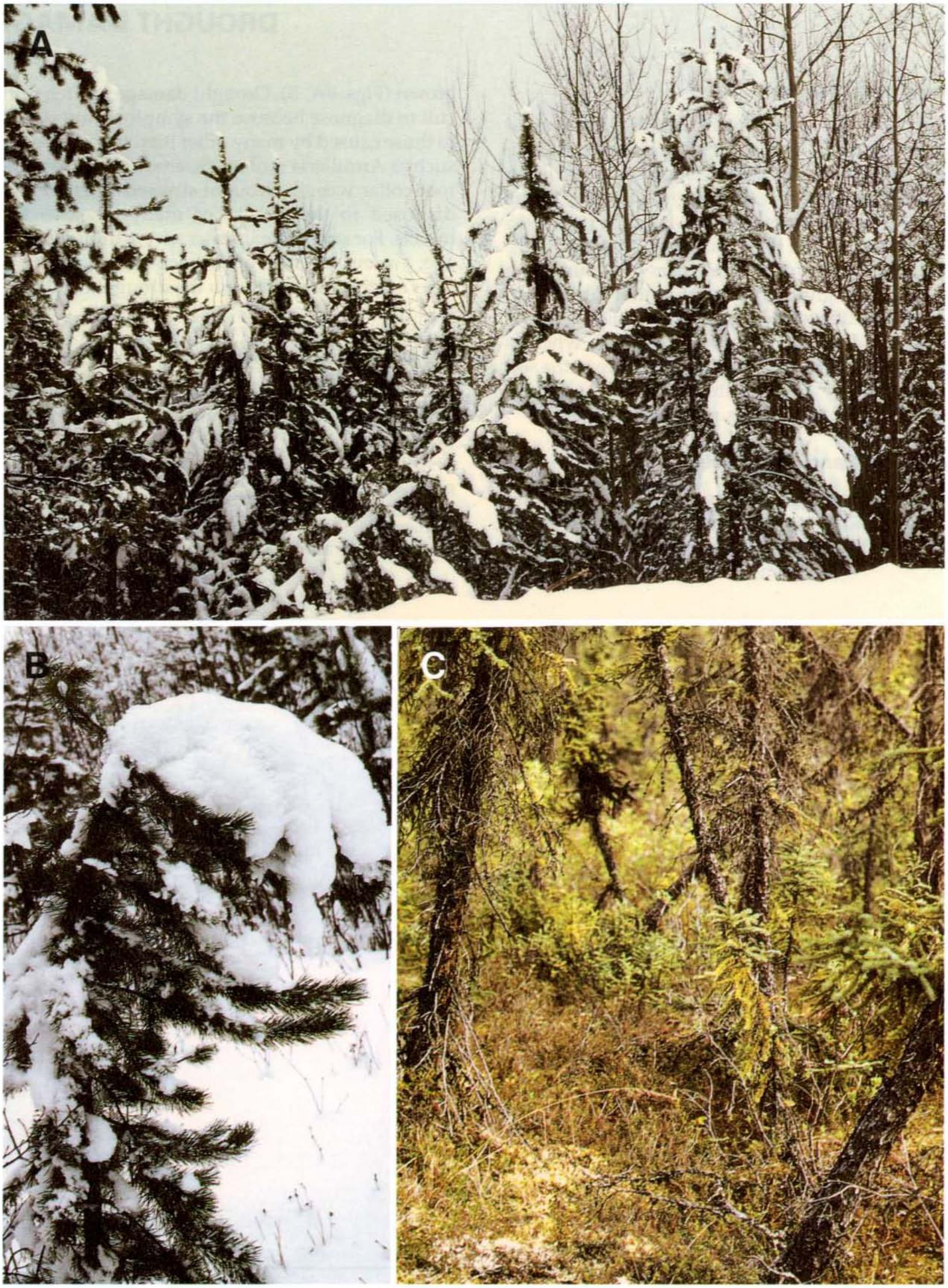
Figure 8. **Drought damage.** **A.** Extensive drought damage of planted red pines. **B.** Drought damage of a natural jack pine stand.


A
B
C

Cause and Damage

Weight of snow and ice glaze (accumulation of ice on foliage and branches of trees due to supercooled rain) may result in extensive physical damage to trees caused by the stress and strain of added weight. Among the common forest tree species in this region, white and black spruces, and jack and lodgepole pines are less prone to snow and glaze damage, while birch and aspen often suffer severe damage. Snow damage is also influenced by stand density, shape of the tree crown, silvicultural practices such as thinning and cutting patterns, and fertilization. More snow damage occurs in high-density stands, and trees with one-sided crown development are more vulnerable to snow damage (Powers and Oliver 1970). There is a report of increased snow damage to nitrogen fertilized jack pine trees. This is probably due to their longer needles, which retain more snow on the crowns (Schnekenburger et al. 1985).

Symptoms and Diagnosis

Bent or broken branches and main stems are evident after heavy snow or ice glaze formation (Figs. 9A, B). It is usually easy to recognize snow or glaze damage. Often trees having structurally weakened stems, due to the presence of stem diseases (pine stem rusts, canker diseases, extensive heart rots, etc.) and root diseases (Armillaria root rot, Tomentosus root rot, etc.) are severely damaged. In the permafrost areas, stems of spruce (mostly black spruce) often lean irregularly in various directions (Fig. 9C). These stands are sometimes called "drunken forests". It has been speculated that this phenomenon is caused by the weight of snow during the winter; however, the proven cause of this phenomenon is irregular soil movements due to uneven freezing and melting patterns of the active soil layer during the summer (Zoltai 1975).

Prevention and Control

To reduce risks of snow damage as well as wind damage (refer to the next section), it is important to plan cutting boundaries. Trees at the edges of harvested areas are vulnerable to snow damage due to unstable root support and exposure to wind. It is also important to plan thinning operations properly to reduce risk of snow damage (Schmidt and Barger 1987).

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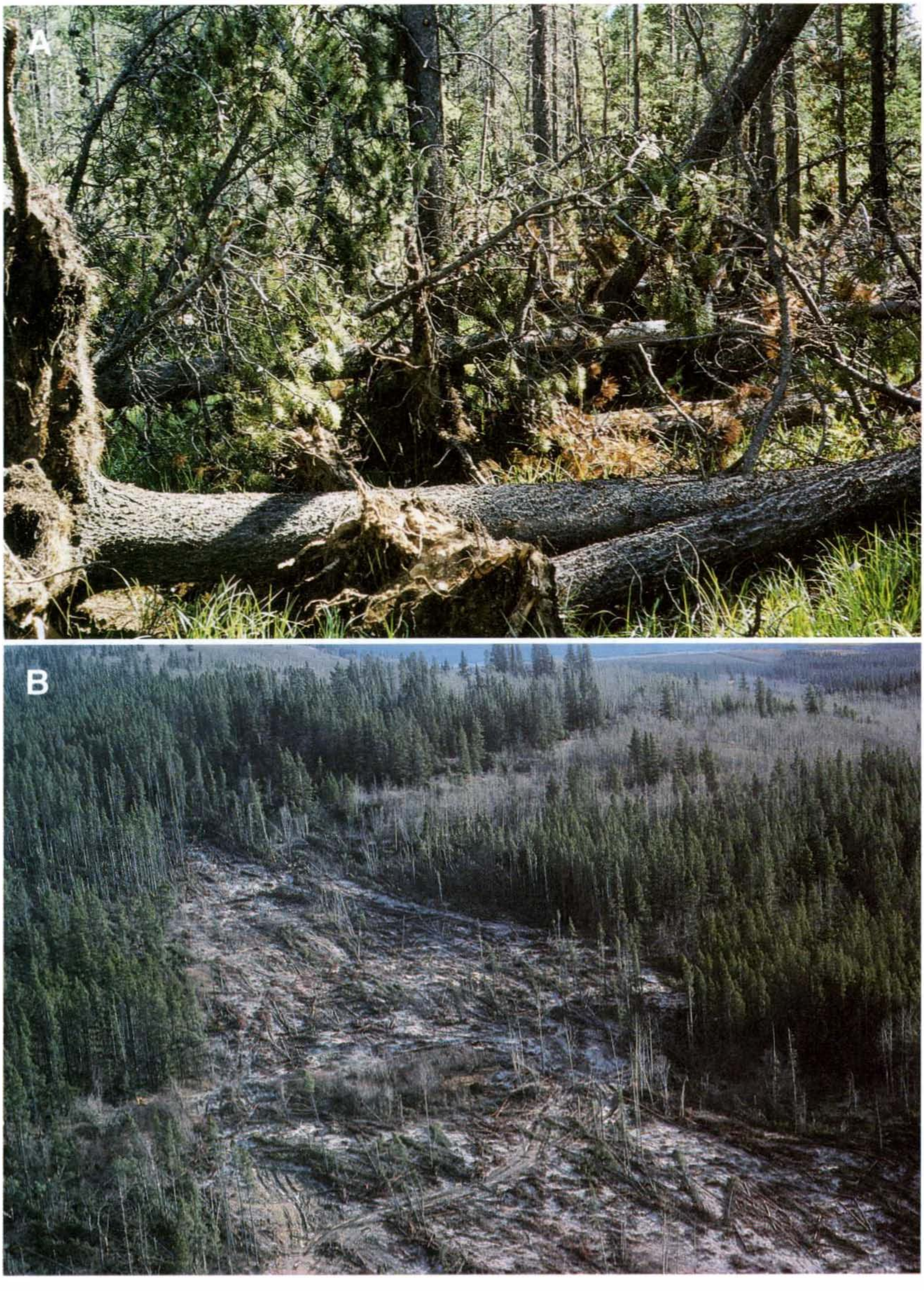
Figure 9. Snow damage. A. Snow damaged lodgepole pine. **B.** Damage caused by snow on a small lodgepole pine. **C.** "Drunken forest" of black spruce in the arctic circle due to melting and freezing activities of permafrost.


A
B

Cause and Damage

Severe wind storms including tornadoes can damage trees by breaking branches and main stems and toppling whole trees. Damage can be restricted to small areas or extended to larger areas. Wind damage often occurs when the mechanical strength of the tree stem is reduced by root rot, various kinds of trunk rot, or canker-causing diseases. Extensive windfall damage often occurs along the margins of clear cuttings (Alexander 1964; Stroempl 1971). Wind flows over the canopy of well-stocked and even-aged coniferous forests, but if gaps are left in the canopy, winds may dip down into the openings and damage trees along the perimeter (Stroempl 1971). Although trees may not be visibly damaged, trees subjected to continuous wind exposure, especially in higher elevations, are vulnerable to winter desiccation damage (Hadley and Smith 1986).

Symptoms and Diagnosis

Wind damage is easily recognized. Many small and large branches break and fall to the ground, but stronger winds often topple and uproot whole trees (Fig. 10A). Up-rooted trees lay parallel to each other as opposed to the crisscrossed pattern found in root-disease centers (Fig. 10B).

Prevention and Control

It is important to consider wind damage possibilities when planning and conducting thinning, harvesting, and planting activities on areas where frequent incidence of wind damage are recorded because thin tall trees, trees exposed to wind, trees with weak root systems, such as trees soon after planting, are generally vulnerable to wind damage. The edges of harvested areas are known to be vulnerable to wind damage; risk of wind throws can be minimized by carefully planning cutting patterns (Alexander 1964; Schmidt and Barger 1987).

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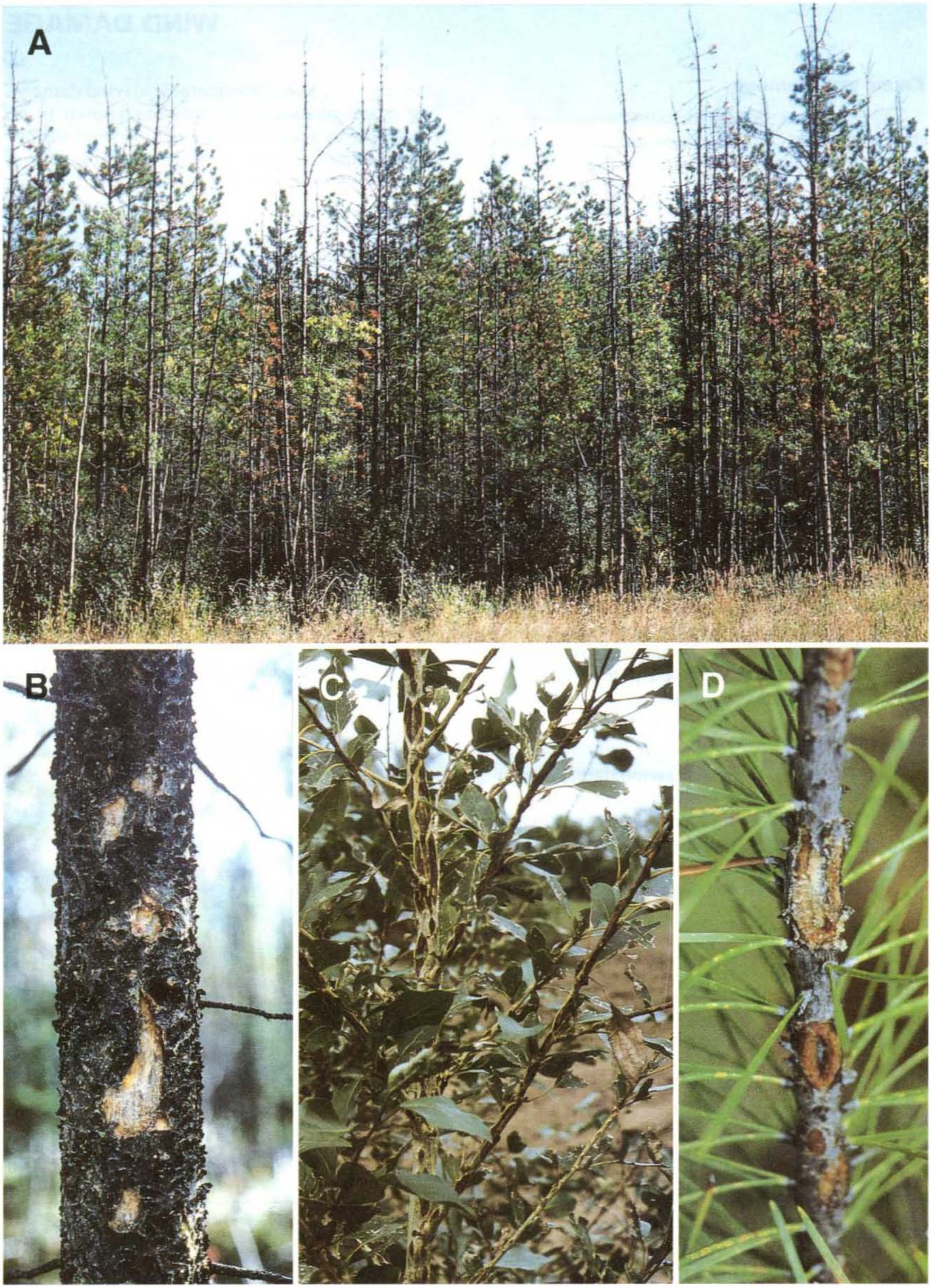
Figure 10. Wind damage. A. Lodgepole pine trees uprooted by wind. **B.** Wind damage of lodgepole pine showing trees laying parallel to each other (photo courtesy of K.I. Mallett).


A
B
C
D

Cause and Damage

Hail storms can occur throughout the year but are less frequent in the winter. The size of the area in which the damage occurs depends on the extent and severity of the hail storms (Fig. 11A). Young stands can be demolished completely by a severe hail storm but impact to larger trees is often insignificant. Hail scars eventually heal, but in the interim they may provide entrance courts for pathogenic fungi.

Symptoms and Diagnosis

Physical damage such as broken branches, shredded foliage, and open-stem wounds of various sizes (Figs. 11B, C, D) are evident soon after hail storms. Damage to stems from previous storms is usually characterized by open blisters surrounded by healing ribs (Figs. 11C, D). Old, hail damage can be confused with cankers or blisters caused by fungi or insects, but it is possible to determine the original cause of damage. Hail damage always occurs on the side of the tree from which the wind was blowing, while damage from other causes usually occur on all sides of the stem.

Prevention and Control

Although there are regional differences in hail storm occurrences and high hazard areas can be identified, no method of prevention or control is available.

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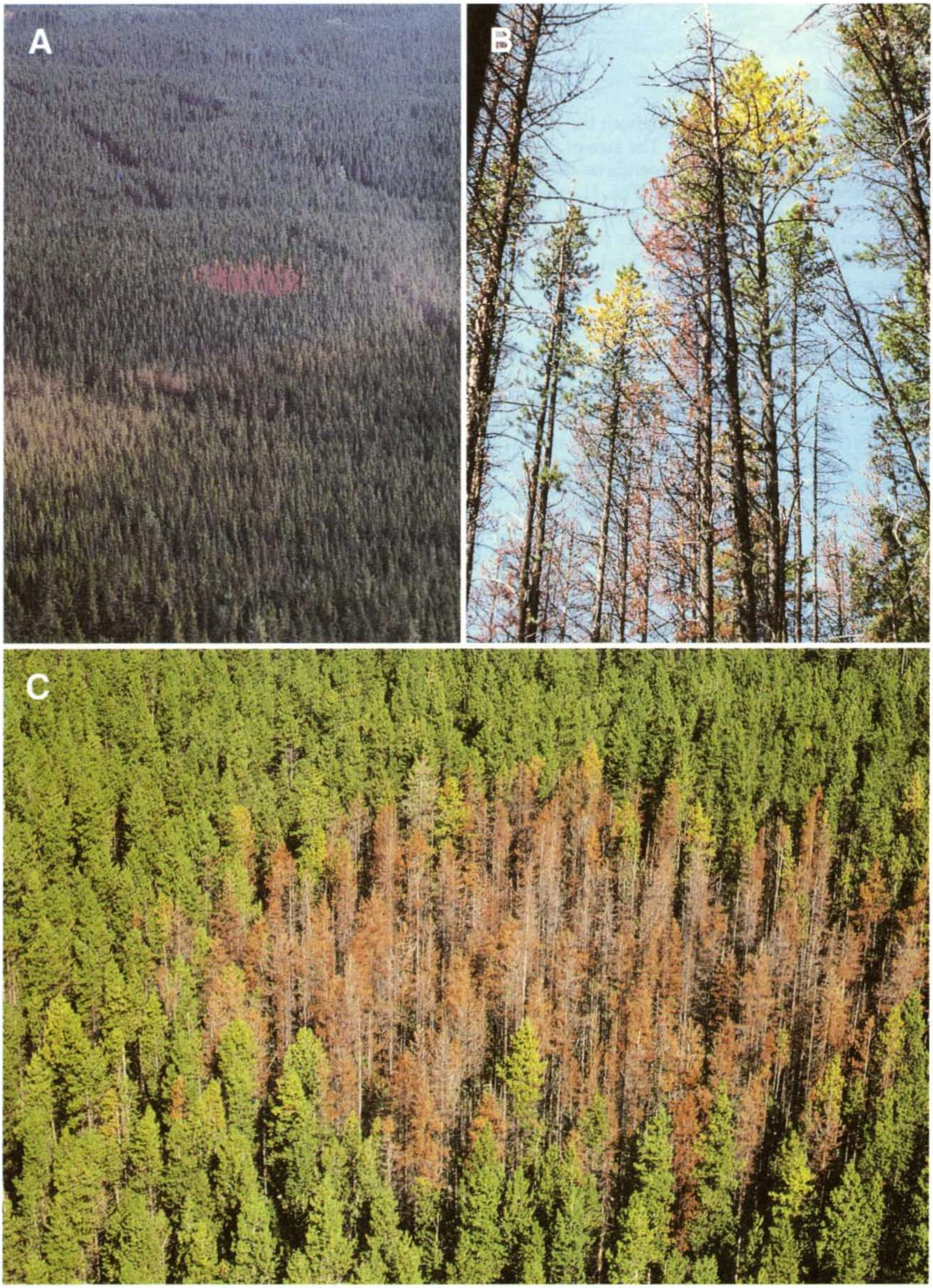
Figure 11. Hail damage. A. A stand of lodgepole pine severely damaged by hail. **B.** Hail damage on a main stem of lodgepole pine. **C.** Severe hail damage of young balsam poplar. **D.** Typical healing hail scars on a lodgepole pine branch (photo courtesy of H. Ono).


A
B
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Cause and Damage

Although many lightning strikes occur without igniting forest fires, lightning is the most prevalent causal agent of forest fires in the prairie provinces. Groups of dead trees in circular patches have been seen from time to time especially in the foothills of the Rocky Mountains. This phenomenon is called "circular tree mortality" or "group tree mortality" (Taylor 1977). The cause of circular tree mortality has not been proven in the prairie provinces, but is likely caused by lightning strikes, as observed and documented in the U.S. and Australia (Minko 1966, 1975; Taylor 1977). Circular tree mortality of a similar nature has also been reported in wheat, potato, and peanut fields. The consequential damage caused by lightning strikes is also known to attract bark beetles, which infest surrounding trees (Schmitz and Taylor 1969) and cause more damage.

Symptoms and Diagnosis

The circles are usually between 0.1 and 0.2 hectares, and about 100–150 trees are discolored and killed in each circle (Figs. 12A, B, C).

Circular tree mortality can be mistaken for stand-opening root rot diseases such as Armillaria root rot or Tomentosus root rot, but trees in circular tree mortality die together in one season rather than gradually over the years as with root rot diseases.

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Figure 12. Circular tree mortality. A. A distant view of a circular tree mortality in a lodgepole pine forest. **B.** Affected lodgepole pine within a circular tree mortality. **C.** Close-up view of a circular tree mortality within a lodgepole pine stand.