FIELD GUIDE TO CAUSES OF

SEEDLING DAMAGE & MORTALITY

IN FIRST YEAR PLANTATIONS

Prepared by
Nursery Staff
Industrial Forestry Association
225 S. W. Broadway/Room 400
Portland, Oregon 97205

Acknowledgements:
Industrial Forestry Association would like to extend its appreciation to the many public and private foresters whose time, energy, advice and criticism greatly improved the quality and accuracy of this publication. Their field experience and observations made this field guide and key possible.

INTRODUCTION

This field guide and key is intended to aid field foresters and technicians in identifying causes of seedling damage and mortality common during the first growing season in Western Washington and Oregon. Some basic background information has been included which may aid reasonable deductions.

Symptoms described in the key (page 1) were observed primarily on bareroot Douglas fir, although many of the same characteristics should be applicable on Ponderosa pine, Western hemlock and noble fir as well as container stock. However, symptoms on species other than Douglas fir may not be similar and container stock rarely shows the same range of problems as bareroot (i.e., moisture loss during handling and root diseases).

This guide and key cannot describe all problems, nor can it describe problems with equal accuracy. Seedlings may suffer from multiple injuries, so it is best to classify the cause of mortality according to the most obvious and accurately defined symptoms. *When symptoms don't fit one category or another, the cause should be classified as "unknown."* The key is designed to facilitate a tentative conclusion based on observed seedling symptoms and their development pattern rather than circumstantial evidence.

Identification of various possible causes of seedling injury depends heavily on initial discoloration of needle, stem, bud and root tissues which, during the incipient stages of decline, can accurately reflect damage associated with injury mechanisms. Temperature and humidity of the planting environment will influence the rate at which symptoms develop and injury symptoms observed in a greenhouse environment will not generally correlate with those in the field. Since characteristics used in this guide were based on field observations exclusively, greater care should be used in making interpretation where extreme weather conditions have prevailed.

As a rule, a minimum of one to 15 trees (including some that appear healthy) should be examined in each planting unit when symptoms appear uniform; 25 to 30 should be examined when symptoms are variable and difficult to interpret.

KEY

(1) A. Intensity of symptoms appears to be enhanced by environmental conditions in the planting unit (highest on certain aspects, in particular topographical positions, in exposed windy areas or related to snow accumulation, etc.) Note of caution: may be confounded with coincident changes in planters, bags, or stock.

(2) 1. **Symptoms appear prior to bud break**

— Cut beneath bark into wood along main stem from root collar to terminal bud.

(3) a. Needle discoloration appears confined to terminal needles, lammas flush or most recent growth. Needles lose turgor as discoloration takes place. Most needles gradually turn deep red. Damage to bark even around stem or branches. Needles below damaged bark green and turgid[1]. Occasionally only the inner bark is damaged along main stem. In such cases discoloration is confined to a very thin layer just outside stem wood — *Freezing Damage to Stem.* Section A.

— Damage appears rapidly after planting (2-3 weeks) for stock planted between late October and mid-December. Normally confined to lush foliage or shoots — Plate No. 1.

— Damage appears slowly after planting (4-8 weeks or longer). Usually indicates more serious damage to main stem tissues — Plate No. 16.

(4) b. Needle discoloration similar to a). Bark tissue shows no discoloration along main stem even when foliage damage evident, although outer bark may seem collasped, shrunken or furrowed. Needles show turgor loss before discoloration occurs. Normally at least some green needles present along lower portion of stem. Often there is a very heavy needle loss on the upper portion of the shoot. Very definite increase in intensity of symptoms with degree of exposure in planting unit. Time of appearance following planting variable — *Winter Desiccation.* Section B, Plates No. 6 and No. 19.

(5) c. Needles turning deep red (all ages) uniformly throughout crown, beginning at tips of needles. Both green and red needles may

---

1. *Turgor*: Internal pressure exerted by cell water against cell wall. As pressure decreases, cell volume decreases because of cell wall elasticity.

have lost turgor. Inner and outer bark uniformly discolored brown above groundline or snowline. May extend throughout shoot or only 2-3 cm above groundline. Margin between damaged and normal bark even around stem and generally coincident with groundline. Symptoms normally develop 4-8 weeks following planting – *Freezing Damage to Lower Stem*. Section A, Plate No. 4.

(6) 2. **Symptoms appear following bud break.**

(7) a. Damage confined to new flush which appears wilted and discolored – *Frost Damage to New Flush.* Section A, Plate No. 5.

(8) b. Damage symptoms common to all ages of needles. Older needles usually brown or red new flush appears wilted turning from light tan to yellow to brown – cut into wood just below bark at above and below root collar including main tap root and/or secondary woody lateral roots.

(9) – Wood tissue in root heavily discolored black, brown, blue, or yellow – *Root Disease.* Section E, Plate No. 7.

(10) – Not as in 2a – *Severe Moisture Stress.* Section B.

(11) c. Foliage (all ages) uniformly chlorotic or bright yellow. Needles fully turgid – *Nitrogen Deficiency*. Section C, Plate No. 3.

(12) B. Intensity of symptoms not apparently related to location in planting unit although may correlate with changes in planters, bags, or stock.

(13) 1. **Symptoms appear prior to bud break.**

– Cut beneath bark into wood along main stem from below root collar to terminal portion of shoot.

(14) a. Needle discoloration occurs uniformly over all ages of needles starting at tips and developing toward base. Needles generally shrunken below indicating turgor loss and desiccation (includes green needles) even though soil moisture plentiful. Color eventually turns deep red.

(15) – Damage or discoloration to bark tissues occurs above and below groundline throughout shoot and root systems. Bark around stem base and root collar separates cleanly from wood in large pieces. Stem wood appears white with no

signs of discoloration from infection. Symtoms normally appear quickly (2-3 weeks) after planting – *Desiccation During Handling.* Section B, Plate No. 2.

(16) – Discoloration of bark tissues occurs only in root system, usually including the region around the root collar. Bark does not separate easily, cleanly, or in large pieces from the wood. Wood white without signs of discoloration. Occasionally only the inner bark appears discolored. Margin between damaged and non-injured bark generally even around stem. Caution: seedling symptoms in the field poorly defined for Douglas fir, appearing similar to Root Disease (Section E) especially if the stock is stored for any length of time following damage – *Freezing Damage to Roots.* Section A, Plate No. 14.

(17) – Bark discolored as above. Margin between healthy and injured bark generally irregular. Wood beneath bark usually shows irregular black, brown, blue, or yellow staining. Bark may feel soft. Inner bark normally adheres to wood. Needles in early stages will generally discolor in groups throughout top independent of needle age or position – *Root Disease*. Section E, Plates No. 10 and No. 11.

(18) – Symptoms as in (5). *Freezing Damage to Lower Stem*. Section A, Plate No. 4.

(19) – Bark discolored along lower portion of stem above ground. Usually does not extend throughout stem in continuous manner. Margin between damaged and healthy tissue normally irregular. Bark may appear soft. Inner bark adheres to wood. Discoloration often extends into wood. Symptoms usually take 4-8 weeks to develop after planting – *Lower Stem Infection*. Section F, Plate No. 8.

(20) b. Needle discoloration generally limited to all tissue above a certain point, fork in double top, terminal needles, lammas flush or most recent growth. Succulent

stem parts adjacent to damaged needles collapse (shrunken and furrowed appearance). Brown or red needles may grade *upward* into green foliage. The latter needles usually appear wilted below (Plate No. 19). Smaller lateral shoots may be the only parts of stem where needle damage is evident.

(21) – Stem damage apparent along stem above root collar. Bark may split at an angle to stem – *Mechanical Damage During Handling.* Section D.

(22) – Both inner and outer bark along shoot discolored brown. Discoloration generally appears in irregular patches penetrating into wood. Margin between damaged and healthy tissue usually irregular. Symptoms normally appear 4-8 weeks after planting – *Disease Infection of Stem.* Section F, Plate No. 18.

(23) – Inner bark or cambium always, outer bark sometimes uniformly discolored brown along entire length of stem above and slightly below point at which needle discoloration begins. Margin between damage and healthy tissue usually regular. Wood shows no signs of stain or discoloration – *Freezing Damage to Stem.* Section A, Plates No. 1 and 16.

(24) c. Needle discoloration not as above. Patterns and coloration are highly variable but may include (1) chlorosis or yellowing, (2) rapid loss of green needles, (3) irregular mottling (gray to yellow) of needles gradually turning brown, (4) rapid turgor loss in green needles (all ages) with a gradual tan to brown appearance. Normally the bark and wood of the stem will not show signs of discoloration in the early stages. The bark around the root collar may, in some instances, discolor brown and deteriorate – *Physiological Deterioration From Storage Conditions.* Section F, Plate No. 12.

(25) – Needles discolor individually throughout shoot, with at least some turgid green needles present. Discoloration normally proceeds center or base of needle and ex-

tends in irregular pattern. Upper portion of stem not shrunken or furrowed – *Fungus Disease of Needles.* Section F.

(26) 2. **Symptoms appear following bud break.** Needle discoloration generally begins at base of stem continuing upward. New flush appears wilted. Lower stem scarred – *Mechanical Damage During Handling.* Section D.

Plate No. 1: Freezing damage to shoot. Note discoloration of late (Lammas) shoots.

Plate No. 2: Desiccation during handling. Note clean separation of bark in large pieces around root collar.

SECTION A

Freezing Damage

Freezing damage to field-planted stock may occur any time of year. It occurs most often during the Fall and Winter months in stock lifted prior to mid-December. Spring frosts also frequently damage stock after growth begins. Damage is normally confined to the new growth and is usually associated with cold pockets or poor air drainage. Typical symptoms are illustrated in Plates 1, 4, 5, 15 and 16.

Freezing damage in the Fall and Winter months is often more difficult to assess since the damage may result from large-scale weather conditions which give the appearance of uniform symptoms in one or several planting units. Freezing damage which occurs in the nursery may not be recognized. This will also result in the appearance of uniform damage over one or several planting units. An understanding of the nature of freezing tolerance development will help in making accurate field interpretations.

Freezing tolerance development (hardening) is believed to be triggered by the gradually shortening days and lower temperatures that begin in later Summer. Within certain limits, tolerance can also be affected by cultural practices such as irrigation and fertilization. Consequently, the tolerance limit of any seed lot can be expected to vary from year to year on the same calendar date. Normal cold storage (0-2°C) apparently does not result in additional hardening beyond that developed at the time of lifting. Stock lifted early and stored for even a few weeks may not be hardy to the temperatures experienced in the field. Similarly, a high-elevation lot may harden at a rate established by the nursery environment, usually considerably milder than the natural environment, and therefore may not be completely hardened to the temperatures common in the field.

Freezing damage is not as common for stock lifted after December, probably because the natural levels of tolerance, even in milder nursery situations, will exceed the common minimum low temperature occurring in Western Oregon and Western Washington. Although this may not be true East of the Cascades, those sites are usually inaccessible until Spring.

The low temperature tolerance of the needles, buds, stems and roots will change at different rates. Early in the Fall (October) the tolerance ranking may be: buds, stem, needles, roots; a few weeks later (December) the ranking may change to: stem, needles, buds, roots. Roots are invariably the least hardy. The upper portion of the stem, or shoot, is also less hardy than the lower portion in the early Fall, but this situation completely reverses as the season progresses.

Freezing damage to roots of bareroot stock is probably not very common since there is an increased concern about leaving stock overnight in bags in the field. Occasionally, poor temperature control may result in the freezing of seedlings in the storage coolers. Container stock that is not sufficiently hardened in the nursery prior to storage appears more susceptible to root freezing damage if left unprotected before planting. Damage symptoms have not been well-defined under field conditions for bareroot stock. If confined to the root tips, symptoms may be too difficult to properly examine in the field. Consequently, great caution should be used before concluding that the injury results from freezing damage to the roots. When seedlings are stored following damage, they become infected. Symptoms will then be confounded with root disease (Section E).

When stem damage from freezing is found it may be worthwhile examining several terminal or lateral buds. Discoloration in these tissues will confirm the diagnosis, but since bud damage is variable the absence of discoloration does not necessarily contradict the initial conclusions (Plate 15).

SECTION B

Moisture Stress, Winter Desiccation and Moisture Loss During Handling

The loss of water from seedlings occurs naturally through the process of transpiration. The failure to immediately replenish this water results in a state of water stress within the plant. The level or degree of water stress can be measured with various instruments. The values are commonly reported in bars of tension. Normal physiological processes are impaired as stress increases and if stress is excessive death will result. Tolerance to varying degrees of moisture stress appears to depend on whether seedlings are fully exposed, as during planting, or growing in the soil. Seedlings in the soil appear quite resistant to stress levels which commonly result in death for more exposed plants. Several studies with Douglas fir have shown that when exposed, as during planting or during lifting and packing in the nursery, seedling vigor is reduced if the internal stress is between -10 and -20 bars. Below -20 bars, severe mortality will occur even if the trees are remoistened immediately.

Mortality symptoms will develop quickly on Fall- and Spring-planted stock, probably as a reaction to the warmer temperatures. Douglas fir seedlings also appear to lose moisture rapidly when lifted in the Fall or Spring, as opposed to the Winter months, even with the same weather conditions. The only good field diagnostic characteristic appears to be the way in which the bark separates (Plate 2). Seedlings which suffer a significant degree of moisture loss during handling, but not enough to cause outright mortality, usually have a marked delay in bud break. Unfortunately, this feature is only discernible under controlled circumstances.

Tests in transplant beds, where seedling moisture stress has been followed, have shown that immediately following planting, moisture stress is high even when the soil moisture is near field capacity. Within one to two weeks the stress gradually drops to low levels, apparently before any visible root activity occurs. Excessive moisture stress may occur following planting with the onset of dry, clear and windy weather. The result is known as Winter Desiccation (Plate 6). This is normally only a problem for stock planted before March in certain geographic locations. Needles are characteristically shrunken on the lower surface before any discoloration takes place (Plate 9). This is due to the loss of cell turgor which causes a decrease in cell volume.

If stress was not too severe the seedling may only drop its needles and break but later in the Spring. Several tests have shown that a combination of freezing and drying conditions are particularly harmful since water, once frozen, cannot move into or within the plant sufficiently to replenish the losses. Damaged tissue such as that which may occur from freezing injury also loses moisture more rapidly than normal tissue.

Inadequate precipitation and warmer temperatures during the Spring and Summer months is an often-cited cause of seedling mortality during the first season following planting. Symptoms of severe stress following bud break are reasonably characteristic. Occasionally, severe deficits develop during the early stages of shoot flushing, especially in cases where seedlings are planted in the late Spring (June). In Douglas fir, where needle elongation occurs more or less simultaneously with stem elongation, water stress limits stem growth between the points of needle attachment. This causes the typical "bottle brush" appearance in some bareroot stock (Plate 13). In pine, stem growth normally precedes needle elongation. As a consequence, depending upon the time at which the stress develops, the new shoot may have a tufted appearance or merely shorter needles.

As internal stress approaches lethal levels the *fully developed* needles lose cell turgor, giving a shrunken or collapsed appearance on the lower needles' surface (Plate 19). Immature needles on recent flushes will generally appear wilted *well below* lethal levels. Previous season's needles generally show turgor loss sooner than fully developed needles on the current season's growth. Needle discoloration will not be apparent at this stage. If the internal stress is then alleviated the needles will regain turgor in a few days, providing the stress has not been lethal. A very common phenomena following recovery from severe internal moisture stress in Douglas fir and pine is the shedding of older needles from the previous year's growth (Plate 13). Needle discoloration naturally occurs during this process, especially in Western hemlock planted in clearcuts. Except for the symptoms regarding moisture loss during handling, the other characteristics are probably similar for Ponderosa pine, Western hemlock and noble fir.

SECTION C

Nitrogen Deficiency

The problem is generally caused by soil conditions in the planting unit as a result of logging or site preparation activities. This may change in the future as closer attention is paid to soil types and other nutritional problems.

Three kinds of soil conditions are commonly associated with chlorotic seedlings during the first season. One is the result of soil compaction around old landings and skid trails (especially those from rubber-tired skidders). The second is the result of tractor scarification of land and windrowing of the vegetation, which causes removal of some topsoil. The third occurs in and around log landings where fine sawdust chips may accumulate. In the first case, nitrogen uptake is probably limited because of the restricted root development in the compacted soil (Plate 3). In the second, too much of the organic layer, from which nitrogen is obtained, is removed. In the third the nitrogen present is monopolized by microorganisms decomposing the fine organic material.

SECTION D

Mechanical Damage

Mechanical damage to the stem of bareroot stock during the lifting and planting operations may cause serious problems. The damage may result in complete girdling of the lower stem. The wound may lose large amounts of moisture or it may be invaded during storage by various pathogens. In any case it often results in mortality although this normally occurs in a relatively small percentage of the stock. Wounds that have had the opportunity to heal during the previous growing season should not cause difficulties.

A mechanical seedling lifter common in several Northwest nurseries causes an angular scar along the lower stem if the machine is not properly adjusted. Mortality usually occurs before bud break if the root system or stem caliper is small.

SECTION E

Root Diseases

Pathogens associated with destruction of root systems in bareroot stock are more likely to originate in the nursery than in the field. The only field-related disease of any significant proportion that has been found to cause mortality in first-year seedlings is Rhizina root rot, caused by the fungus *Rhizina undulata*. This disease seems to be confined to portions of Western Washington, North of a line through Mt. Rainier, where it develops in response to intense slash burns. It is relatively easy to identify because of the characteristic fleshy, liver-colored fruiting bodies which develop around dying seedlings. More detailed information on this disease can be obtained from State or Forest Service pathologists.

Marginally infected root systems of seedlings in the nursery bed probably account for a great majority of the plants which die from root diseases upon planting in the field; however, this is not certain. Storage conditions may encourage disease spread among root systems to the extent that they can no longer regenerate themselves after planting. The warmer and wetter the storage environment, the greater will be the opportunity for disease spread within and among the seedlings. Soil incorporated with stock in packing bags is also believed to be a source of infectious pathogens. Few diseases have been specifically identified because of the expertise which is required and because of the subsequent decay of dead tissue by the many soil saprophytes present. The latter organisms make it difficult for the layman to base any conclusions upon the examination of the fine roots. When the root system has been damaged by other means, the finer roots are often quickly invaded by these organisms. Observations should be confined to the woodier portion of the root system (Plate 11).

Foliage symptoms often appear irregularly throughout the shoot because of predominant vascular connections between certain portions of the shoot and individual lateral roots which may undergo decay more rapidly than others (Plate 10).

When mortality appears due to a root disease, a qualified pathologist should be consulted, since its occurrence may indicate a serious problem at the nursery or a new and perhaps potentially damaging disease.

SECTION F

Storage and Related Problems

Research has established at least two causes of seedling decline under normal cold storage conditions. One common problem with seedlings in storage results from disease infection, particularly of the shoot. A number of common organisms have been identified (Botrytis, for example). Infection may result in destruction of all or part of the stem or foliage tissue. Some organisms may spread from dead tissue into living tissue: a top killed by frost, a dead branch or dead needles, possible results of shading in very dense beds. Scars may also act as sources from which pathogens may spread and infect stem tissue (Plates 18, 8).

For certain foliage fungi, such as *Rosellinia herpotricodes,* only those needles with infections will exhibit damage symptoms, consequently the presence of at least some turgid, green needles six to eight weeks after planting indicates that the infection has not caused serious stem damage.

Physiological deterioration is also suspected as another cause for increased mortality following storage. Unfortunately, symptoms are not well described. It is usually assumed that seedlings die as a result of their inability to regenerate roots adequately. Symptoms may appear similar to Winter desiccation even though soil moisture is sufficient. The actual reason for the decrease in root regeneration capability is not understood. With the general movement towards later (December through February) lifting for long-term storage, the problem has been less frequent. Moisture loss is usually not a problem during storage because of the predominant use of polyethylene-lined kraft bags in Pacific Northwest nurseries. Rapid needle dropping and chlorosis soon after planting has also been correlated with possible non-pathogenic physiological changes in storage, probably as a result of heating in the bags.

Maintaining bag temperatures just above freezing (1°C) is probably the single most important means of reducing seedling losses during storage.

SECTION G

Miscellaneous Problems

Extreme surface soil temperatures occasionally cause mortality in planted seedlings. High temperatures will kill the inner and outer bark tissues near the ground surface. Although seedlings so affected normally survive the first season, they will die in the second or third. The girdling stops translocation of food materials to the root system, preventing growth needed to sustain the shoot. Heat-damaged seedlings are easily identified by a pronounced swelling of the stem just above the killed tissue (Plate 17). Heat damage is not restricted to bare soil conditions, but can occur if a seedling touches a rock, log or another material that absorbs or reflects heat.

Exposure to full sunlight may cause the destruction of chlorophyll in the needles of Western hemlock. The symptoms appear as a bleaching or whitening of the normally green tissues. It is easy to recognize since overlapping needles will provide sufficient shade to prevent de-greening. This results in sharp patterns of green and white corresponding to the natural shading among needles (Plate 9). The problem is caused by excessive shading during the growth period in the nursery. The needles will then become "shade adapted" and susceptible to bleaching upon exposure to full sunlight. It is unknown to what extent this problem results in actual mortality.

Plate No. 3: Nitrogen deficiency. Plug seedling planted in compacted skidder tracks.

Plate No. 5 (above): Frost damage to new flush. Note damage to leaves on surrounding brush.

Plate No. 4 (left): Freezing damage to lower stem. Note the sharp margin between damaged and healthy tissue near the groundline.

Plate No. 6 (right): Winter desiccation. Note loss of foliage and gradual discoloration of remaining needles. Green needles may appear as in Plate No. 19.

Plate No. 7 (left): Root disease *Rhizinia undulata*. Root system heavily discolored on closer examination. Fruiting bodies not shown.

Plate No. 8 (right): Lower stem infection. Note irregular margin of discoloration along inner bark. Note also the dead branches above that may have been source of infection.

Plate No. 9 (left): Solarization. Note green strips in lower needles corresponding to overlap or shading from other needles.

Plate No. 10 (above): Root disease. Note irregular discoloration of various portions of the shoot (noble fir). Root system shows clear signs of decay (not visible in photo).

Plate No. 11 (above): Root disease. Note discoloration in larger woody roots.

Plate No. 12 (below): Deterioration from storage conditions. Note needle loss and irregular discoloration along shoot. Seedling in photo remained alive.

Plate No. 13 (above): Moisture stress. Note discoloration of older needles following recovery.

Plate No. 14 (above): Freezing damage to roots. Note contrast between normal light-colored stem bark and damaged root bark.

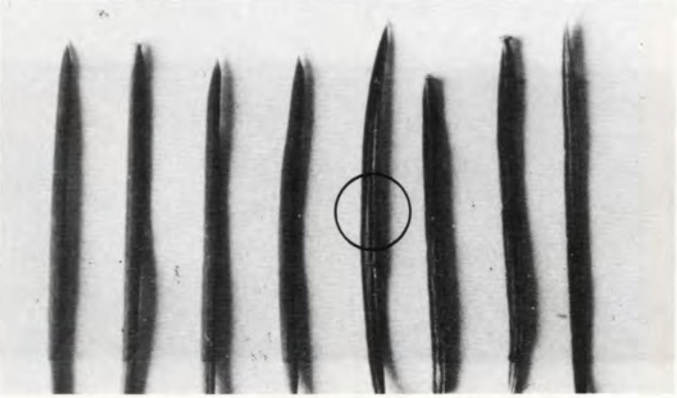
Plate No. 15 (below): Freezing damage to buds. Terminal bud is undamaged (green) while the two laterals have been killed.

Plate No. 17 (above): Heat damage. Note collapse of bark around root collar as a result of high soil surface temperatures.

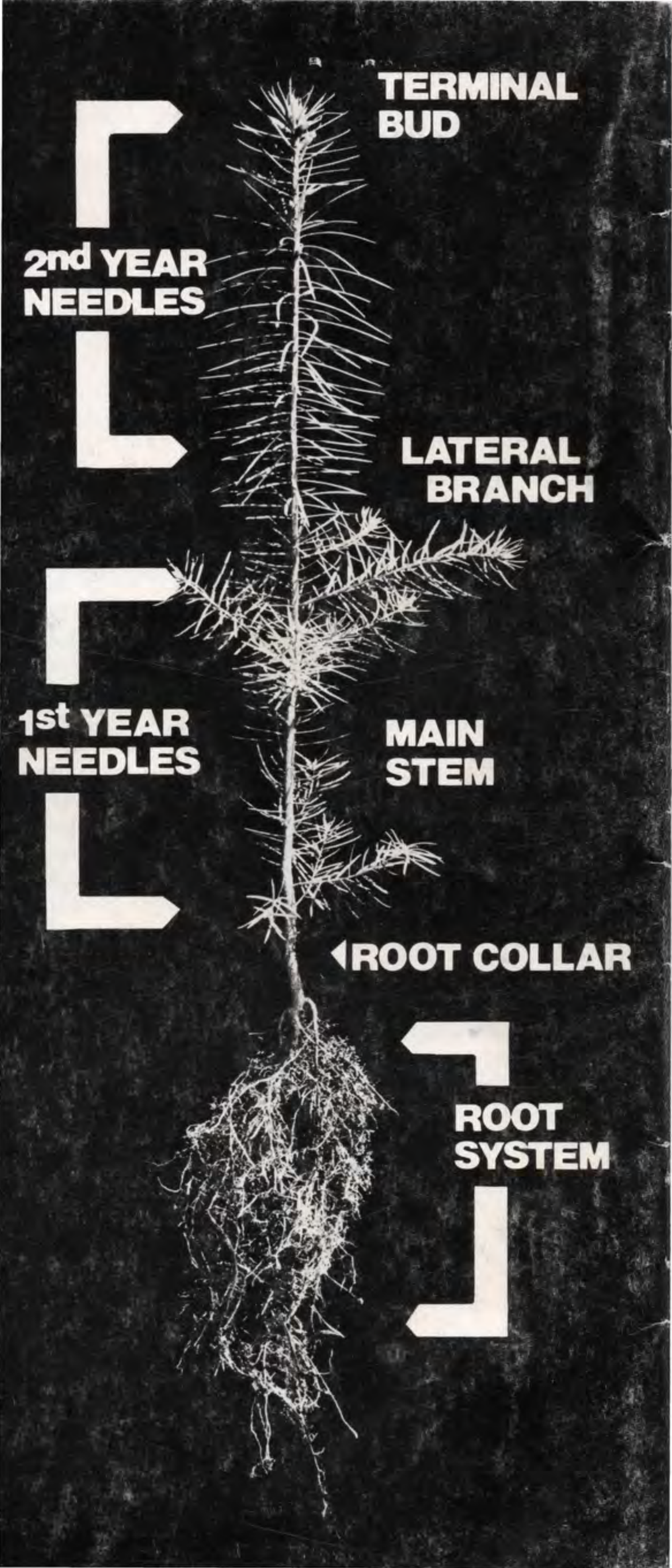
Plate No. 16 (above): Freezing damage to stem. Note green needles on lower stem and bud breaking occurring just below damaged portion of shoot.

Plate No. 18 (right): Disease infection of stem. Note irregular and discontinuous damage along stem.

Plate No. 19 (below): Turgor loss or wilting. Note shrunken or furrowed appearance along lower needle surface (right). Needles are still green, although severely wilted.



PLATES


TERMINAL BUD
2nd YEAR NEEDLES
LATERAL BRANCH
1st YEAR NEEDLES
MAIN STEM
ROOT COLLAR
ROOT SYSTEM