COMPARISON OF 8 PHYSICAL BARRIERS USED FOR PROTECTING DOUGLAS-FIR SEEDLINGS FROM DEER BROWSE

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INTRODUCTION

DEER BROWSE AND REGENERATION SUCCESS

The success or failure of forest regeneration efforts in western Oregon and Washington often depends on adequate control of animal damage to young seedlings. Cutover and partially stocked forest lands provide excellent habitat for animals that clip or browse young seedlings. Black and Dimock (1969) estimated that animals were responsible for roughly one out of five reforestation failures. The Cooperative Animal Damage study of coniferous plantations in Oregon and Washington (1963-1975) found that animals damaged an average of 30 percent of all unprotected Douglas-fir seedlings each year on the 165 plots studied (Black et al. 1979). Browsing by deer and elk was by far the most common, accounting for more than two-thirds of the total damage. Animal damage costs the timber industry several million dollars each year in Oregon and Washington. Considering that humans have all

Name/Position	Landowner	Plot "Handle"
Mike Bondi *Clatsop County* *Forestry Extension Agent*	*Mr. and Mrs. Rankin*	*Jewell, OR*
Dave Crooker *Silviculturist*	*Burlington Northern*	*Morton, WA*
Rick Fletcher *Linn/Benton County* *Forestry Extension Agent*	*a) Mr. B. Udell* *b) Mr. D. Drusella* *c) Mr. L. Mohnike*	*Lebanon, OR* *Scio, OR* *Alsea, OR*
Orlando Gonzales *Silviculturist*	*USFS*	*Galice, OR*
Bob Graul *Silviculturist*	*Champion International*	*Glide, OR*
Chal Lengren *Columbia County* *Forestry Extension Agent*	*Mr. B. Johnston*	*Mist, OR*
Paul Oester *Coos County* *Forestry Extension Agent*	*a) Fred Messerle & Sons, Inc.* *b) Mr. W. Krieger* *c) Mr. B. Daniels*	*Coos Bay, OR* *Gold Beach, OR* *Myrtle Point, OR*
John Patrick *Silviculturist*	*BLM*	*North Umpqua/Glide, OR*
Steve Tanner *Reforestation Forester*	*USFS*	*Butte Falls, OR*

but eliminated the key predator to adult deer and elk, the wolf, this situation is not likely to improve.

THE PROBLEM

Deer are a problem to reforestation predominantly during the seedling establishment phase. Harvesting, site preparation and wildfires severely disturb the land, replacing living trees with vegetation characteristic of early secondary succession (annual and perennial herbs and grasses with scattered woody shrubs/tree sprouts or seedlings). This creates an ideal habitat for browsing by deer. In the Douglas-fir region local occurrence of black-tailed deer can increase dramatically in response to the improved forage availability that follows human-induced disturbances. In interior forests of central and eastern Oregon and Washington, browsing by mule deer damages seedlings which occur along their fall and spring migration routes and within their lower elevation winter range.

Browsing seldom occurs more than 4 feet (1.2 m) above the ground, except in winter when snowpack allows deer a "step stool" to reach tops of conifer seedlings projecting through the snow. Browsing of new growth usually leaves a clean break that becomes blunt after the broken face of the succulent shoot forms a callus during healing. Browsing of more mature woody vegetation creates a ragged, splintered stem during the dormant season, but in early spring browsing may cause the bark to slip leaving a stripped stem some distance below the break (Animal Damage Control Book).

Damage to planted seedlings usually occurs in one of two ways. First, seasonal height growth is prevented if terminal and primary laterals are browsed. Repeated browsing during the season or from year to year produces a stunted, bushy tree with numerous laterals all vying for the terminal position. Second, the physical lifting that frequently occurs when the branchlet is plucked off can tear newly initiated fine roots, adding to the total injury encountered by the seedling. This can increase the incidence of mortality, particularly on harsher sites. Browsing may occur throughout the year, but is normally highest during the period of rapid growth in the spring.

ADDRESSING THE PROBLEM

There are several approaches available for minimizing browse damage:

Hunting

Special hunts which permit shooting of both sexes can be, although rarely are, successful in reducing the local deer population to a level that is tolerable in terms of minimizing browse. Killing of does and fawns is, in most cases, not acceptable to the general public from a moral point of view.

Habitat Manipulation

Techniques such as planting preferred forage, removal of vegetation or planting tree species minimally browsed by deer can be very effective when used properly. However, to insure success, its effectiveness, impact on the site and effect on seedling vigor should be carefully evaluated for the area in question <u>before</u> operational implementation.

Silvicultural Modifications

The planting of large trees, planting as late in spring as is consistent with other reforestation requirements and breeding for non-palatable genotypes are examples of methods which can be used by silviculturists to avoid browse damage. As with any "tool" success is likely to be site or area specific and cautious evaluation should preceed implementation.

Repellents

Numerous chemical repellents (odor or taste) have been tried in an attempt to ward off hungry deer. Although a few have proven very successful, in general, their short-term persistance and application constraints limit their practicality on many sites.

Fencing

Although fencing is extremely effective in preventing browse damage by deer the high costs of material (reusable) and labor tend to limit its use to high value plantations.

Physical Barriers

The application of protective devices which physically prevent deer from browsing can be very effective, when installed properly and when precautions are taken to use each device in only those situations to which it is best suited.

This report focuses on physical barriers because they are the most widely used approach in the Pacific Northwest, and because the availability of information on the effectiveness of individual devices and their impact on seedling vigor is dangerously insufficient, especially considering the extent to which many have been employed operationally. Although the picture is still cloudy, due primarily to the variability associated with the multitude of steps in the reforestation process, several factors have been identified which allow formulation of basic guidelines for alternative selection. In addition, a few do's and don'ts surfaced during the testing which have helped develop appropriate utilization criteria for several alternatives. (The overwhelming desire to find "the answer" was quickly thwarted by reality.) There is no single solution that is applicable to all areas, each case must be carefully assessed in light of one's knowledge of the site and the reforestation strategy being employed.

PHYSICAL BARRIERS

The various types of physical barriers available for individual tree protection (see drawing in Appendix 1) can be divided into two groups: (1) physical barriers for total tree protection and (2) physical barriers for terminal-only protection.

PHYSICAL BARRIERS FOR TOTAL TREE PROTECTION

(1) Chicken-wire shaped to form cylinders can be installed around seedlings. These chicken-wire cylinders require stakes for support.

(2) Vexar tubes are rigid polypropylene-mesh tubes, with diamond shaped patterns. The material is photodegradable.

(3) Flexible netting, like Vexar tubes, is made of photodegradable polypropylene. The finer plastic mesh expands to easily slip over the seedling.

(4) Reemay sleeves are spun polyester sheets sewn into 2-inch (5-cm) diameter tubes and cut to a 28-inch (70-cm) length. They completely enclose the seedling.

PHYSICAL BARRIERS FOR TERMINAL-ONLY PROTECTION

(1) Paper bud caps are rectangular pieces of weatherproof paper (5.5" x 8.5"; 13.75 x 21.25 cm) that are folded lengthwise and stapled around the terminal leader and bud.

(2) Reemay bud caps are made of spun polyester. The material is slightly heavier than that used in making the sleeves and comes in 4-foot x 100-foot (1.30-m x 30-m) rolls that, in this study, were cut into 16-inch x 4-inch (40-m x 10-cm) rectangles. These rectangular pieces are then stapled around the terminal.

(3) Leader tubes, like Vexar tubes, are made of photodegradable polypropylene. They are available in a diameter range of 1 to 2 inches (2.5-5 cm) at lengths of 12, 18, and 24 inches (30, 45, 60 cm). The diamond shaped mesh is smaller than in Vexar tubes.

(4) No nibbles are plastic caps that are slipped over and rest on top of the terminal bud.

DIRECTION OF THE STUDY

The project was initiated to reassess old methods and evaluate new methods for physically preventing deer browse. The effect of different protective barriers on browse prevention, susceptibility to protector loss and terminal damage, treatment impact on seedling survival and shoot elongation, and cost variables were compared. The individual studies were conducted on a wide variety of forest sites between the 42 and 47 parallel west of the Cascade Crest (see map in Appendix 2). The approach was used to assess the degree of treatment variability over a range of sites, mild to harsh, and to obtain information on the positive and negative aspects of each treatment on individual sites.

One of the first physical barriers tested (Marquis 1977) for individual tree protection was a chicken wire cylinder, 8 to 18 inches (20-45 cm) in diameter, about 3 feet (90 cm) high and supported by wood stakes. Evaluation of these devices revealed good browse prevention and occasional height growth enhancement, but were hampered by high costs and seedling distortion. The latter was caused by laterals, and occasionally terminals growing through the side. This often resulted in crumpling of the wire cage, further hindering normal seedling growth patterns. Since chicken wire deteriorates very slowly, trees were girdled when their diameter exceeds that of the cylinder (8- 18 inches; 20-45 cm, 10-20 years) or, in the case of side escape, the diameter of the diamond mesh (0.5 to 1.5 inches; 1.3-3.8 cm, 3-5 years).

In 1968, following a cooperative study between the Fish and Wildlife Service and DuPont, Inc., the Vexar tube was developed. Studies using Vexar tubes revealed some of the same advantages and disadvantages as the chicken-wire mesh. They prevented wildlife damage, provided occasional height growth enhancement, but did not solve the occasional problem of potential terminal restriction and, although cheaper than chicken-wire mesh tubes, they were still expensive. Attempts to overcome some of these disadvantages resulted in the proliferation of numerous devices for physically protecting seedlings against browsing. Most devices were not adequately evaluated prior to implementation. Indiscriminate use of many of these devices has lead to complications on numerous sites.

The impact that browse damage can have on seedling survival and/or growth, coupled with the lack of published information on many alternatives being used operationally and the propensity for many to "leap prior to looking" provided both the driving force and the justification for this investigation. Since the use of physical barriers poses no apparent threat to the environment, does not harm the deer and does not exclude wildlife from their prime habitat it is a desirable approach to browse control.

THE STUDY

This study comparatively evaluates 8 different physical barriers for individual tree protection on 14 different sites (see Appendix 2; not all devices were tested on all the sites). Data from one, and in some cases, two growing seasons, have contributed to the analyses. Incidence of deer browsing, seedling height growth, survival of the seedlings, condition of the seedlings and of the physical barriers was recorded in the spring and the fall. Appendix 3 gives the description of the study areas. Appendix 4 shows the experimental design. Chi-square ($\times^2$) test of independence was used for analyzing data on browsing, seedling survival, occurrence of protector loss and occurrence of restricted or bent terminals (all at the

95% confidence level). To test differences among treatment means in height growth, t-tests for paired plots were run (at the 95% confidence level).

RESULTS AND DISCUSSION

The findings for the different physical barriers were highly variable on a plot-to-plot basis, indicating that success with a particular device may often be site specific depending on site characteristics (type and quantity of precipitation, slope and aspect, air and soil temperature, prevailing winds, pressure from other animals, and, of course, the subtle behavioral differences among different deer populations). Consequently, the positive and negative aspects of various alternatives may need to be re-evaluated by site (especially if marked differences from our test sites are evident) to insure selection of the best control method, or combination of methods.

TOTAL TREE PROTECTION VS. TERMINAL-ONLY PROTECTION

All total tree protections used in this study caused deformation of lateral branches. However, the relative importance of these lower branches once shaded by laterals produced on the protected terminals after 2-3 years, will become decreasingly beneficial to overall seedling growth (food use exceeds food production) and will evantually be naturally pruned. Interestingly, the shading effect of the total tree protection devices may, in some instances, have a positive effect since the seedlings' nursery needles are retained longer, which one might expect to increase its growing potential. A more severe impact occurs when the terminal is restricted or bent, which suppresses height growth and prolongs the period of browse susceptibility.

Physical barriers developed to protect only the terminal were found to cause terminal bending more often on small seedlings than on large seedlings. It is therefore advisable to use unsupported terminal protection devices on larger seedlings or to provide support for terminal protectors when their use on smaller seedlings is desired. When using total tree protection devices on small seedlings, adequate support in the form of laths, metal pins or bamboo stakes should always be used. Larger seedlings, on the other hand, may not need support to remain erect and grow properly.

An added benefit of total tree protectors is that they also provide protection from girdling or clipping by animals such as mice, rabbits, mountain beaver, grouse, etc.

All physical barriers tested were found to be highly effective in protecting trees against deer browsing. However, browsing was found when the physical barrier had either been blown off by strong winds or removed by members of a resident elk herd. Two of the study sites were completely wiped out by pesky elk [the Mist site and the Jewell site (second year)]. They showed no preference for protector alternatives as they ripped off and often consumed all evidence (data from these sites has, for obvious reasons, been excluded).

Few incidences were observed in which browsing occurred after the terminal emerged from protection of the physical barrier. If observed, it indicates browsing by deer is not confined solely to the early spring stages of shoot elongation. For the site in question this may necessitate adjustment of the physical barrier (both total tree and terminal-only), or in the case where a total tree protector was used, additional terminal-only protection.

CONTROL TREES
(See Appendixes 5 and 6.)

Browse

All unprotected control trees were browsed to a significantly greater extent than trees protected by physical barriers. This was true whether the site was subject to high (85%) or low (25%) browse intensity.

Mortality

On most sites mortality of control trees was not significantly different from mortality of protected trees. However, on the Butte Falls site mortality of control trees, and trees protected by Reemay sleeves, was high (significantly higher than for shade carding which was also being evaluated for microsite amelioration). The greater incidence of mortality on this harsh, southwest aspect at 4,000 feet elevation site, occurred as a consequence of a prolonged heat wave in August, 1981. This was substantiated by the survival data taken prior to and after the heat wave. Shade carding revealed no apparent benefit over controls the first year, but significantly reduced mortality after 2 growing seasons.

VEXAR TUBES

The Vexar tubes used in this study were 30 inches (75 cm) tall and 3 inches (7.5 cm) in diameter, with a diamond shaped mesh. When used on small seedlings or on sites with strong winds, Vexar tubes require a stake for support. The rate of decomposition of the polypropylene material varies with fiber thickness (finer netting breaks down faster than thick, rigid-tubing), and susceptibility of the material to photodegradation by ultraviolet radiation.[1] The earlier prototypes of Vexar tubes were exceedingly durable and frequently girdled young trees as their diameters exceeded that of the tube. This rarely occurs with the current product.

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[1] The polypropylene material contains compounds which reflect high energy UV radiation (Bill Bennett, International Reforestation Suppliers, pers. comm.). The quantity of these compounds may vary by batch.

Browse

Overall, protection against deer browsing by Vexar tubes was found to be very good. Browsing varied from 0% to 15% (significantly less than for control trees; no significant difference between Vexar tubes and other protectors was found). The 15% browsing occurred on the Galice site, and was due to the fact that the terminals had grown out of the top of the tubes.

Mortality

Mortality on most sites was not significantly different between controls and trees protected by Vexar tubes, or other physical barriers and was considered to be low (4.6% overall). However, on the North Umpqua site mortality of trees protected by Vexar tubes was found to be moderate (12%). Since this phenomena was observed on only one site, it is believed that it may have resulted from root damage caused by improper stake placement during installation of the tubes.

Terminal restricted
(See Appendixes 5 and 6.)

The occurrence of restricted terminals was significantly less for trees protected by Vexar tubes than for trees protected by most of the other physical barriers. Factors which influence the incidence of terminal restriction and damage when using Vexar tubes include failure to use a support stake to hold the tube upright and improper vertical orientation of the staked tube. Both situations increase the likelihood that the terminal will get hung up and either bend downward, escape through the side, or abort.

Protector loss

The incidence of protector loss for Vexar tubes was low, averaging 8.5% overall. The occurrence of strong winds on the Messerle site increased this figure to 17.8%.

Height growth
(See Appendix 7.)

There was no significant difference in height growth between trees protected by Vexar tubes and control trees on 4 of the 5 sites (Glide, Gold Beach, Coos Bay (year 1), North Umpqua). On the Galice site, height growth of trees protec ted by Vexar tubes was significantly greater (34%) than height growth of control trees.

FLEXIBLE NETTING

The polypropylene netting is lighter, has a finer diamond mesh than Vexar tubes and is flexible so that it can be expanded to slip over the seedling easily. The netting then contracts around the seedling allowing the seedling to stand upright without support. Netting is available in several weights, the 8 ml (light) and 13 ml (heavy) being the most frequently used. Both types cause bunching of the laterals resulting in a distorted growth pattern. Improper application and wind prone sites enhance the likelihood of a similar fate for the terminal. As the laterals make contact, the flexibility of the material hinders penetration of the branch through the netting, the opposite of what was originally expected. This pushes the netting outward, further constricting the top and decreasing the chances of free terminal escape. After one to several years branches usually burst through the netting. Unfortunately, upward extension has been disallowed and they are again susceptible to browse.

Browse

Overall protection against deer browsing by both light netting and heavy netting was found to be good (no significant difference between netting and other protectors was found). However, trees protected by flexible netting are, as with other alternatives, susceptible to browsing when the laterals and terminals penetrate through the netting and when protection is blown off.

Mortality

Mortality for trees protected by light netting and heavy netting was low, averaging 3.6% overall for light and 4.4% overall for heavy netting, and not significantly different from other protectors or control trees.

Terminal restricted

Restriction or bending of the terminal was found to be less troublesome for heavy (15.2%) than for light netting (35.3%), but was still considered moderate. In many cases the terminal penetrated through the side of the netting, frequently resulting in a bent stem. Proper, uniform application is much more difficult to monitor and the incidence of moderate to strong winds may flip netting over the elongating shoot, negating efforts to insure correct application.

The use of netting on smaller seedlings as a total seedling protector appears to be less risky than when used as a terminal protector on large, well established seedlings. Overall, only 31% of the terminals were restricted on small seedlings, as compared to 54% for large seedlings.

The problem can be avoided for small, fully protected seedlings by using 3 bamboo stakes to spread the netting far enough apart to prevent terminal hangup. The first year netting on the Galice site was installed using 3 stakes and that year the occurrence of restricted terminals was low (0%). However, while adjusting the netting for the second growing season 2 of the 3 stakes were removed, resulting in a high rate of restricted terminals (65%).

Protector loss

Overall, loss of protector was low to moderate for light netting (7.9% overall) and high for heavy netting (22.9 overall). Apparently heavy netting is more susceptible to strong winds than light netting.

Height growth

There was no significant difference in height growth between trees protected by light netting and control trees on 2 of the 5 sites (Morton and Jewell). Height growth of trees protected by light netting was significantly greater than height growth of control trees on the Galice site (18%) and on the Coos Bay site (45%). On the Glide site, height growth of trees protected by light netting was significantly less (18%) than height growth of control trees.

There was no significant difference in height growth between trees protected by light netting and trees protected by Vexar tubes on 3 of the 5 sites (Galice (year 1 *and* 2), Coos Bay (year 1)). Height growth of trees protected by light netting was significantly less than height growth of trees protected by Vexar tubes on the Glide site (23%) and on the Coos Bay (year 2) site (41%).

No significant difference in height growth between trees protected by heavy netting and control trees was found on 2 of the 4 sites (Alsea and Jewell). No information is available from the Coos Bay sites, due to extensive browse damage to control trees.

There was no significant difference in height growth between trees protected by heavy netting and trees protected by Vexar tubes, on the Coos Bay (year 1) site. On the Coos Bay (year 2) site height growth of trees protected by heavy netting was significantly less (42%) than height growth of trees protected by Vexar tubes.

There was no significant difference in height growth between trees protected by light netting and trees protected by heavy netting on the 3 sites where both protectors were tested (Jewell, Coos Bay (year 1), Coos Bay (year 2)).

REEMAY SLEEVES

The spun polyester Reemay sleeves are quite porous, more durable than weatherproof paper (more resistant to tearing), and easily secured by staples. On extremely windy sites and in the absence of a support shaft the constant whipping can hasten disintegration of the material. The thin polyester material reduces incident radiation of sunlight by 40%, which encourages retention of shaded nursery needles thus enhancing growth potential. However, it also causes bunching of lateral branches limiting air movement across the seedling's foliage and likely increasing susceptibility to heat-induced damage on xeric sites. An important feature of the sleeve is that terminal escape is forced to occur through the top. Although a support shaft may be needed for small seedlings to disallow terminal restriction caused by the drooping sleeve, terminals of larger, well established seedlings have no trouble pushing up through the sleeve as long as it does not become snagged on brush.

Browse

Reemay sleeve protection against deer browsing was found to be very good. Only 1% overall (significantly less than for control trees) of the trees protected by Reemay sleeves were browsed. This occurred only when terminals escaped through the top or when laterals escaped through the side after deterioration of the sleeves.

Mortality

When used properly and on the right site, mortality for trees protected by Reemay sleeves was not significantly different from mortality of trees protected by other alternatives or control trees. However, Reemay sleeves appear to have an adverse effect on seedling survival on hot, dry sites, particularly with south facing slopes. On the Butte Falls site mortality for trees protected by Reemay sleeves was very high (38.3% the first year and 58.3% the second year). This high mortality rate coincided with a heat spell in August, 1981 with an apparent carryover effect in 1982. A similar, but less severe response was observed on the Galice site. Lack of air movement among bunched branches inside the sleeve disallows adequate dissipation of sensible (convection) and latent (vaporization) heat, which could have attributed to overheating and tissue injury. This may be compounded by the "greenhouse effect" (excessively high CO_2 concentrations) which can signal stomatal closure and limit transpirational cooling.[2]

Hartwell and Calkins (1978) used perforated (0.25 inch; 0.62 cm diameter) Reemay sleeves on Douglas-fir seedlings to avoid heat induced damage. Preliminary results were found to be encouraging, but caution is needed, since this method has not been verified on xeric sites.

Terminal restricted

Reemay sleeves when allowed to flop without support, caused terminals to bend and become contorted within the sleeve. This was particularly evident on small seedlings (plugs and 2-0's) and in situations where the drooping sleeve became snagged by adjacent brush. Three ways to avoid this problem are, (1) insert an arrow shaft or bamboo stake down through the sleeve, (2) cut off the sleeve 4 to 8 inches (10-20 cm) above the terminal bud and return later to adjust the sleeve as the terminal protrudes, and (3) only use sleeves as bud caps (terminals only) on large seedlings.

Reemay sleeves were not supported the first year on the Coos Bay site. This resulted in restriction and/or bending of 44.4% of the terminals. Uncontrolled trailing blackberry vines snagging the drooping sleeve tips appeared, in part, responsible for this high level of terminal interference. The sleeves were supported with bamboo prior to the second growing season. Half

2. The risk of mortality resulting from buildup of heat and CO_2 concentrations increases with all types of total seedling protectors that cause bunching or branches. If browse damage is severe enough to warrant protection on potentially hot, dry sites it may be necessary to protect only the leader and for smaller seedlings to provide terminal protector support with a lath or 0.25 inch circular stake.

(24.4%) of the terminals, restricted or bent the previous year, straightened out, the remaining 20% did not. If sleeves had been supported from the beginning all terminal restriction could likely have been prevented.

Larger seedlings (big 2-1's and annually browsed, well established seedling brushes) are generally able to support the sleeves without support, if snagging does not occur. This was observed on both the Glide and Morton sites, where 9 and 14% of the terminals were bent versus 13 and 12% for leader tubes and 50 and 58% for netting, respectively.

Protector loss

Loss of protector was found to be low (7.0% overall). This figure can be easily decreased by securing the sleeve with staples at the base of small seedlings, or to a small lateral branchlet when used as a drooping bud cap on large seedlings.

Height growth

No significant difference in height growth between trees protected by Reemay sleeves and control trees was found on 3 of the 5 sites (Butte Falls, Glide, Coos Bay (year 1)). Height growth of trees protected by Reemay sleeves was significantly greater than height growth of control trees on the Morton site (15%) and on the North Umpqua site (17%).

There was no significant difference in height growth between trees protected by Reemay sleeves and trees protected by Vexar tubes on 3 of the 5 sites (Glide, Coos Bay (year 1), Coos Bay (year 2)). Height growth of trees protected by Reemay sleeves was significantly greater than height growth of trees protected by Vexar tubes on the Galice (year 1) site (16%) and on the North Umpqua site (16%).

PAPER BUD CAPS

Paper bud caps are rectangular pieces of weatherproof paper (5.5 x 8.5 inches, 13.75 x 21.25 cm) that are folded lengthwise and stapled around the terminal leader and bud. When correctly applied, they provide protection of only 2 to 4 inches of terminal elongation in the early spring. However, in many instances this allows enough time for shoot tissue to become more rigid, for foliage to accumulate compounds of less nutritive value and for other preferred browse species to become more prominent, the result being a shift in feeding focus away from conifers to herbs and woody brush. If browsing is observed after terminals begin to escape a quick application of a chemical retardant (BGR - Deer Away) should be used since the relatively weak elongating shoot cannot support the weight of an "adjusted" bud cap. Paper bud caps require annual adjustment or replacement.

Browse

Protection against deer browsing using Paper bud caps was found to be good (6.7% overall) and significantly less than for control trees. However, strong winds on the Jewell site caused a substantial protector loss, leaving the unprotected trees susceptible to browsing.

Mortality

No mortality was observed for trees protected by paper bud caps. However, heat damage to terminals may be a potential hazard on hot, dry sites with southwest aspects, as indicated by occasional damage (less than 10%) observed on moderate sites.

Terminal restricted

The incidence of restricted terminals was found to be low (5.3% overall) for paper bud caps. Results from the Jewell site indicate that occurrence of restricted or bent terminals increases on sites subjected to strong winds. This is particularly evident when paper bud caps, which have been securely attached, are used on smaller seedlings.

Protector loss

The loss of paper bud caps was found to be very high (28.5% overall). Loss increased with increasing wind velocity and/or the occurrence of wind eddies. An easy way to decrease the rate of protector loss is to staple the paper bud cap to a small, lower branchlet. Although the distal portion of this branch may die the influence on seedling health will be negligible compared to terminal loss due to browsing.

Height growth

Height growth of trees protected by paper bud caps was not significantly different from height growth of control trees on the 6 sites where this protector was tested (Alsea, Morton, Glide, Jewell, Gold Beach and Myrtle Point).

On the Glide and Gold Beach sites where both paper bud caps and Vexar tubes were tested, no significant difference in height growth of the trees either protected by paper bud caps or Vexar tubes was found.

REEMAY BUD CAPS

Reemay bud caps are not available commercially in precut form. They were used in this project as a comparison to paper bud caps because of their durability, light weight, and quick drying character (porous). The spun polyester material, available on 4 x 100 foot (1.30 x 30 m) rolled sheets, was cut into 16 x 4 inch (40 x 10 cm) rectangles to provide for longer protection of the elongating terminal. The longer length also allowed more flexibility in obtaining secure attachment to the seedling.

Browse

Overall, protection against deer browsing was found to be good for Reemay bud caps (7.1%). However, if bud caps were not securely attached, loss during strong winds made trees susceptible to browsing.

Mortality

As with paper bud caps no seedling mortality was observed. However, occasional (less than 10%)

damage to terminals by spot heating was observed for both Reemay and paper bud caps. This suggests that the incidence of such damage could increase on harsh, southwest aspects.

Terminal restricted or bent

The occurrence of restricted or bent terminals was found to be low when using Reemay bud caps (9.6% overall).

Protector loss

Loss of Reemay bud caps was found to be moderate to high (18.3% overall), especially on sites with strong winds. The incidence of protector loss can be minimized by stapling the bud cap to a small branchlet or by stapling the bud cap to an arrow shaft inserted adjacent to the stem so the cap rests around the terminal.

Height growth

There was no significant difference in height growth between trees protected by Reemay bud caps and control trees on 2 of the 3 sites (Alsea, Jewell). On the Coos Bay (year 1) site, height growth of trees protected by Reemay bud caps was significantly greater (55%) than height growth of control trees.

No significant difference in height growth between trees protected by Reemay bud caps and trees protected by Vexar tubes was found on the Coos Bay (year 1) site. On the Coos Bay (year 2) site, height growth of trees protected by Reemay bud caps was significantly less (52%) than height growth of trees protected by Vexar tubes.

LEADER TUBES

Leader tubes are polypropylene mesh tubes with diameters ranging from 1 to 2 inches (2.5-5 cm) at lengths of 12, 18 or 24 inches (30, 45, 60 cm). The diamond pattern is too small for lateral escape of the elongating terminal, although needles can get hung up which can initiate terminal bending. The leader tubes used in this project measured 1.66 inch (4 cm) in diameter and 24 inches (60 cm) in length.

Browse

Leader protection against deer browsing using leader tubes was found to be very good, averaging 3.2% on the three sites where this device was tested.

Mortality

There was no mortality of trees protected by leader tubes.

Terminal restricted or bent

The occurrence of restricted or bent terminals was found to be moderate when using leader tubes. Important to note in the current studies was the use of leader tubes on only larger, well established seedlings. Although leader tubes can be used on smaller seedlings, modifications to accommodate their weight (use of arrow shaft for support) may be needed. Minimizing terminal restrictions or bending could be accomplished by stapling the tube to an arrow shaft, slipping the terminal inside the tube and securing the arrow shaft in the ground adjacent to the seedling (see Appendix 1). This will also reduce the influence wind has on inducing terminal hangup during flopping of the leader-protected terminal.

Protector loss

The occurrence of protector loss was found to be low when using leader tubes (5.2% overall). However, stapling of the leader tube to a lower branchlet or pinching it by stapling was necessary to achieve this low incidence of protector loss, particularly on smaller established seedlings.

Height growth

There was no significant difference in height growth between trees protected by leader tubes and control trees on 3 of the 4 sites (Morton, Gold Beach, Myrtle Point). On the Glide site, height growth of trees protected by leader tubes was significantly greater (26%) than height growth of control trees.

On 1 of the 2 sites both leader tubes and Vexar tubes were tested. There was no significant difference in height growth between trees either protected by leader tubes or Vexar tubes (Gold Beach). On the Glide site, height growth of trees protected by leader tubes was significantly greater (21%) than height growth of trees protected by Vexar tubes.

NO NIBBLES

No Nibbles are plastic caps that can be slipped over the top of terminal buds and are about the same size and shape as plastic finger sheaths used by doctors to splint sprained fingers. It was hoped that these conical caps would not interfere with apical growth and simply be pushed upward as the leader extended. Unfortunately, the sensitivity of apical meristems in Douglas-fir seedlings to pressure is high, and even these lightweight caps exert enough force to stop normal growth (aborted terminal) and leader extension in most cases. No Nibbles were also highly susceptible to loss by wind.

CONCLUSIONS

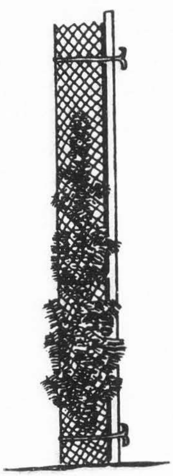
1. *All 8 physical barriers tested effectively prevented browse damage*. Browsing of unprotected control trees ranged from 5 to 85%, averaging 40% overall.
2. *Physical barriers rarely affected seedling survival.* Reemay sleeves increased mortality during a 1981 heat wave in southern Oregon.
3. *Deformation of the terminal was enhanced on some, but not all, sites by flexible netting, Reemay sleeves, leader tubes and Vexar tubes*. Support shafts, when properly used, can minimize or even eliminate terminal deformation. No Nibbles frequently induced terminal abortion.

4. *Loss of physical barriers by wind did occur and was generally greater for terminal than whole-seedling protectors.* Loss was greatly reduced by stapling to small lateral branchlets. Extensive damage to physical barriers, but not necessarily to seedlings, by elk occurred on 2 sites.

5. *Height growth was not adversely affected by any physical barrier.* Vexar tubes, Reemay sleeves, light netting, leader tubes and Reemay bud caps increased height growth on some, but not all, sites.

6. *Alternatives are available for physically protecting seedlings from browsing at lower cost than Vexar tubes and stakes, and with comparable effectiveness* (see Appendix 8).

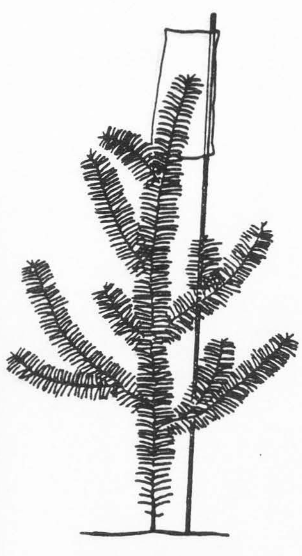
Appendix 1. Drawings of Physical Barriers



Vexar tube (VT)
supported by a lath

Flexible netting (LN,HN)
unsupported

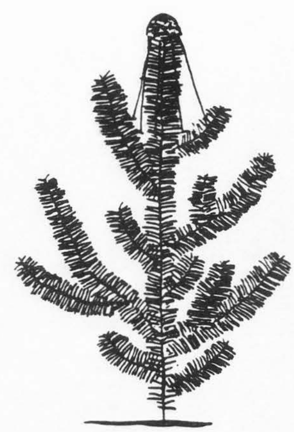
Reemay sleeve (RS)
supported by a bamboo stake



Reemay bud cap (Rbc)
stapled to an arrow shaft

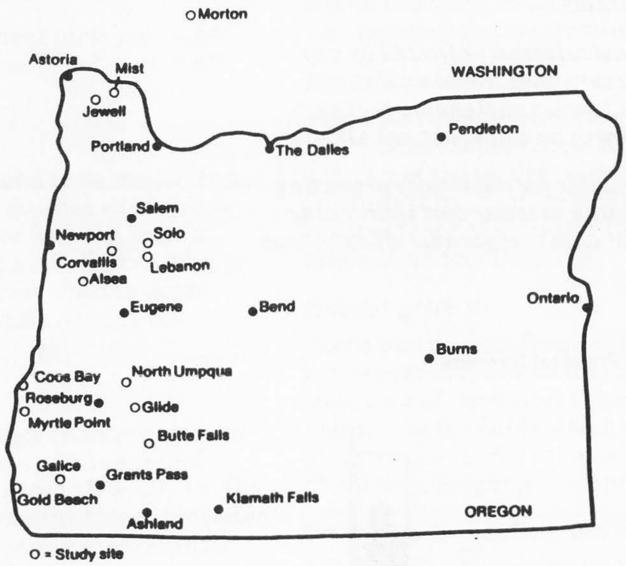
Paper bud cap (Pbc)
stapled to a lower branch

Leader tube (LT)



No nibble (NN)

Appendix 2. Location of the study sites



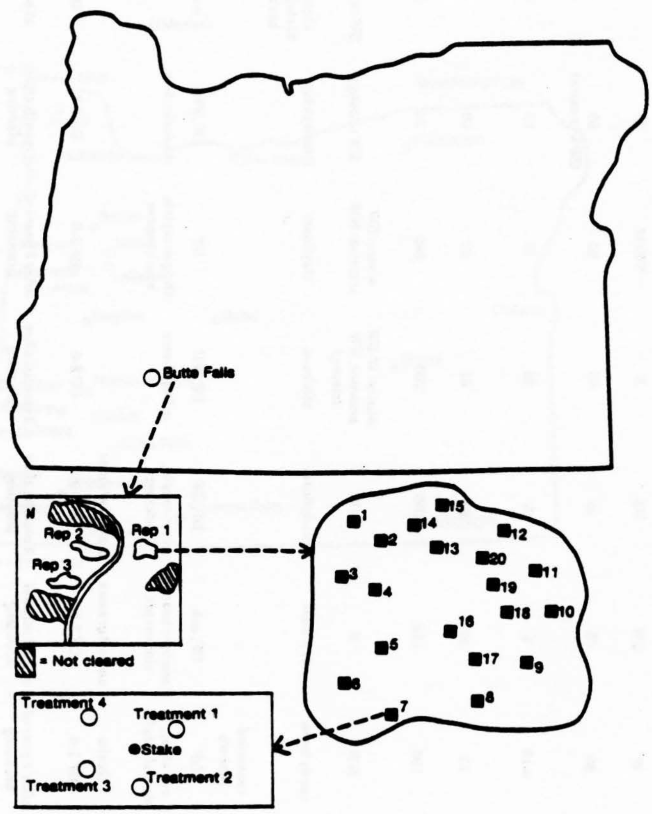
Appendix 3

Description of the Study Sites

Characteristic/Area	Morton	Butte Falls	Jewell	Glide	Galice	Alsea	Lebanon	Scio	Coos Bay	Gold Beach	North Umpqua	Corvallis	Myrtle Point
Slope (%)	10-15	15	0	10-40	60	0-5	10	0-20	0-30	12-30	30	0-5	0-7
Aspect	W	NW, SW	N-NW	NE	N-NE	W	SW	NE	E	SW/W	S	E	
Annual precipitation (inches)	57 (38 in snow)	45-50	75	51	65	80	45	45	65	80	60 (80% in snow)	45	65
Pr. during growing season (in.)	1.7		15-20	5	7	8-10	5	5	20	25	12	6-8	20
Temp. growing season (°F)	50	62	65-70	56	61	57	62	62	61	61	60	65	61
Length of growing season (days)*	180	90	150	150	200	190	180	180	200	240	90	180	200
Prevailing winds	SW	winter: S summer: W (low/moderate)	summer: W/NW winter: S/SW (strong)	W-SW (moderate)		NW	W	NW	winter: W-SW summer: NW (strong)	winter: SW summer: NW	SW (strong)	SW (moderate)	winter: W-SW summer: NW
Soil type	silty/clay/loam	loamy (#34)	Nehalem/ Walluski	loam/lt. clay loam	loam/sandy loam	sandy loam	clay/loam	sandy/loam	silt/loam	clay/loam	rocky/clay	a) clay/loam b) clay/loam + bark mulch	silt/loam
Ecological habitat			converted pasture			converted pasture							
tree	DF, WH	DF, WF		DF	DF	DF	DF, oak	DF, GF	DF, WH	DF	DF, WH	nursery	DF
shrub	berberis	trailing bb deerbrush		firewood, blackberry		red alder, bigleaf maple	western hazel, vine maple	vine maple, blackberry	salmonberry	Oregon myrtle blue blossom	rhododendron		
herb			orchardgrass bent grass			Oxalis	annual grasses	annual grasses					grass
Kind of seedlings planted	DF 1-1	DF 2-0	DF 2-0	DF 2-0/2-1	DF 2-0	DF 2-0	DF 2-0	DF 2-0	DF 2-0	DF 2-0	DF 2-0	DF 2-0	DF 2-0
Protector installation prior to seasonal budburst	after 2 years of browsing	two weeks after planting	2 years after planting	after 3 years of browsing	3 months after planting**	after 1 year of browsing	after 2 years of browsing	2 months after planting	2 months after planting	after 2 years of browsing	1 month after planting	at planting	2 months after planting

* Beginning of budburst to time diameter growth ceases.
** After budburst.

Appendix 4. Experimental Design



Appendix 5

Percent browse, mortality, terminal restricted or bent and protector loss, per treatment.

Treatment	Area	Browse %	Mortality %	Terminal Restricted %	Protector Loss %
C	*Glide*	4.7	0.0		
	Butte Falls (1) §	-	8.3		
	Butte Falls (2) §	-	26.6*		
	Jewell	28.0	-		
	Galice (1)	85.0	6.7		
	Galice (2)	36.7	10.0		
	Morton	25.5	-		
	Messerle (1)	35.6	-		
	Messerle (2)	51.1	0.0		
	Gold Beach	33.3	0.0		
	North Umpqua	-	6.0		
	Alsea	55.6	-		
	Myrtle Point	36.4	-		
Total mean		39.5	7.2*		
VT	*Glide*	0.0	1.6	8.0	0.0
	Galice (1)	0.0	1.7	-	-
	Galice (2)	15.0**	3.3	11.7	-
	Messerle (1)	6.7	-	2.2	17.8***
	Messerle (2)	0.0	6.6	11.1	6.6
	Gold Beach	0.0	2.4	2.4	9.5
	North Umpqua	-	12.0	-	-
Total mean		3.6	4.6	7.1	8.5
LT	*Glide*	0.0	0.0	13.0	3.2
	Morton	6.8	-	11.9	-
	Gold Beach	0.0	0.0	12.0	7.1
Total mean		3.2	0.0	12.3	5.2
Pbc	*Glide*	0.0	0.0	0.0	0.0
	Jewell	32.0†	-	18.0††	26.0***
	Morton	1.7	-	1.7	-
	Gold Beach	0.0	0.0	0.0	59.5
	Alsea	0.0	-	6.7	-
Total mean		6.7	0.0	5.3	28.5
RS	*Glide*	0.0	0.	9.0	3.2
	Butte Falls (1)	-	38.3†††	25.0	-
	Butte Falls (2)	-	58.3†††	-	-
	Galice (1)	0.0	11.7	-	-
	Galice (2)	5.0	10.0	63.3¶	-
	Morton	0.0	-	13.6	-
	Messerle (1)	0.0	-	44.4¶	6.7
	messerle (2)	0.0	2.2	20.0¶¶	11.1
	North Umpqua	-	6.0	-	-
Total mean		1.0	10.1	29.2	7.0
Rbc	*Jewell*	24.0†	-	14.0	24.0***
	Messerle (1)	2.2	-	2.2	8.9
	Messerle (2)	2.2	0.0	8.9	22.0***
	Alsea	0.0	-	13.4	-
Total mean		7.1	0.0	9.6	18.3
LN	*Jewell*	16.0	-	12.0	8.0
	Messerle (1)	6.7	-	24.4	8.9
	Messerle (2)	6.7	4.4	37.8	13.2
	Glide	1.6	0.0	50.0	1.6
	Galice (1)	0.0	5.0	0.0	-
	Galice (2)	3.3	5.0	65.0	-
	Morton	5.1	-	57.8	-
Total mean		5.6	3.6	35.3	7.9
HN	*Alsea*	0.0	-	15.6	-
	Jewell	12.0†	-	10.0	40.0
	Messerle (1)	6.7	-	6.7	24.4
	Messerle (2)	6.7	4.4	28.9	4.4
Total mean		6.5	4.4	15.2	22.9
NN	*Jewell*	32.0†		28.0	48.0

§ (1) = first year, (2) = second year
* Harsh site, total mean was 4.4% without Butte Falls site
** Leaders had elongated beyond the top of the tube
*** Protector loss due to strong winds
† Occurrence of browsing after protector loss
†† Restricted terminals due to strong winds
††† Harsh site, total mean: 7.5% without Butte Falls site
¶ Not staked
¶¶ Staked second year - carry over effect

Appendix 6

Overall Rating

	VT	RS	Staked RS	Rbc	Pbc	LT	LN	HN	NN	Control
Browse deterence	Good (3.6%)	Good (1.0%)	Good	Good (1.5-7.1%)[1]	Good (0.4-6.7%)[1]	Good (3.2%)	Good (4.9%)	Good (8.5%)	Good[1]	39.5%
Lateral growth interference	Moderate	High	High	NA	NA	NA	High	Moderate	NA	
Terminal growth deterence	Moderate (7.1%)	High (29.2%)[1]	Low	Low (9.6%)	Low (5.3%)	Moderate (12.3%)	Very high (35.3%)	Moderate (15.2%)	Very high (28.0%)	
Effective[2] lifetime (yrs)	3-4	1-3	1-3	1-3	1-2	3-4	2-2.5	2-2.5	2-3	
Maintenance & readjustment	Low	Moderate	Low	Moderate	Moderate	Moderate	High	High	High	
Mortality	Low 4.6%	Low (7.5%) to high (>20%) on harsh sites		Low (0%)	Low (0%)	Low (0%)	Low (3.6%)	Low (8.5%)	3	4.4-7.2%
Loss of protector	Low (8.5%)	Low (7.0%)	Low	Moderate (18.3%)	High (28.5%)[1]	Low (5.2%)	Low (7.9%)	Moderate (22.9%)	High (48.0%)	
Average costs of material/tree (¢)	>16[4]	10	>10[5]		1.6-2.3[6]	6.2 (24x1.5")	1.8 (24")	6.1 (24")		

1 See Appendix 5
2 Effective lifetime refers to the number of years before breakdown of the device. Vexar tubes, netting and Reemay are chemically light sensitive and will degrade more quickly in full sunlight.
3 See section 3.9.
4 Add 15-20 cents for a lath.
5 Add 2-5 cents for a stake, 3.5-4.5 cents for a chaft.
6 Costs vary with quantity purchased.

Appendix 7

Height growth + (cm)

Site	Comparison	Height Growth	
Alsea	C vs. HN	43.2 vs. 37.4	N.S.
	C vs. Pbc	42.8 vs. 39.9	N.S.
	C vs. Rbc	43.1 vs. 42.0	N.S.
Butte Falls	C vs. RS	72.7 vs. 76.2	N.S.
Coos Bay (1)	C vs. RS	7.6 vs. 8.1	N.S.
	C vs. VT	7.6 vs. 9.0	N.S.
	C vs. LN	7.6 vs. 10.6	S+
	C vs. Rbc	7.9 vs. 12.0	S+
	VT vs. RS	9.1 vs. 8.4	N.S.
	VT vs. HN	9.2 vs. 9.7	N.S.
	VT vs. LN	9.5 vs. 10.5	N.S.
	VT vs. Rbc	9.5 vs/ 11.1	N.S.
Coos Bay (2)†	VT vs. Rbc	24.9 vs. 16.4	S+
	VT vs. HN	26.1 vs. 17.5	S+
	VT vs. LN	31.2 vs. 17.9	S+
	VT vs. RS	25.6 vs. 22.4	N.S.
Galice (1)†	VT vs. LN	64.5 vs. 66.0	N.S.
	VT vs. RS	65.7 vs. 77.5	S
Galice (2)	C vs. LN	83.7 vs. 138.0	S+
	C vs. VT	110.2 vs. 162.0	S+
	VT vs. LN	136.3 vs. 154.8	N.S.
Glide	C vs. Ln	28.5 vs. 22.5	S+
	C vs. Pbc	26.1 vs. 25.7	N.S.
	C vs. VT	26.4 vs. 27.3	N.S.
	C vs. RS	27.5 vs. 29.1	N.S.
	C vs. LT	25.5 vs. 32.3	S+
	VT vs. LN	29.1 vs. 21.7	S
	VT vs. Pbc	27.8 vs. 25.9	N.S.
	VT vs. RS	27.4 vs. 29.3	N.S.
	VT vs. LT	27.4 vs. 33.8	S
Gold Beach	C vs. LT	25.5 vs. 24.6	N.S.
	C vs. Pbc	25.9 vs. 26.7	N.S.
	C vs. VT	26.2 vs. 28.1	N.S.
	VT vs. LT	27.8 vs. 25.4	N.S.
	VT vs. Pbc	28.5 vs. 26.9	N.S.
Jewell	C vs. Pbc	92.8 vs. 91.5	N.S.
	C vs. NN	93.2 vs. 91.4	N.S.
	C vs. LN	93.0 vs. 92.2	N.S.
	C vs. Rbc	93.6 vs. 96.5	N.S.
	C vs. HN	94.4 vs. 100.1	N.S.
Morton	C vs. Pbc	44.5 vs. 41.3	N.S.
	C vs. LN	44.2 vs. 44.9	N.S.
	C vs. LT	44.9 vs. 46.8	N.S.
	C vs. RS	46.2 vs. 51.7	S
Myrtle Pint	C vs. Pbc	26.1 vs. 25.3	N.S.
	C vs. LT	27.3 vs. 25.8	N.S.
	C vs. LT + stake	26.2 vs. 36.5	S
North Umpqua	C vs. VT	30.7 vs. 30.6	N.S.
	C vs. RS	29.6 vs. 36.5	S
	VT vs. RS	29.1 vs. 35.8	S+

+ Trees with bent or restricted terminal and trees with protector loss were excluded from the height growth analyses.
S: Significant (at 95%). S+: Highly significant. NS: Not significant.
†: Controls were browsed to such an extent that no comparisons could be made between treatments and controls.

Appendix 8

The Price You Pay for Browse Protection

Alternative	Materials	$/Acre (500 seedlings) Contract	Maintenance*	Total
1. Vexar tubes/lath	80/85	80	35	280
2. Reemay sleeves +	50	60	20	130**
support shaft	18	70	25	163
3. Heavy netting +	31	45	25	101
support shafts (3)	54	75	30	190
4. Light netting +	10	45	25	80
support shafts (3)	54	75	30	169
5. Paper bud caps	10	40	25	75
6. Reemay bud caps	15	40	20	75
7. Leader tubes +	33	60	25	118
support shaft	18	70	30	151
8. BGR (Deer Away)	25	30	55***	110

* Does not include replacement cost of lost or destroyed materials, just the cost of walking the site and making necessary adjustments.

** The total cost of the top line (Reemay sleeves alone = 130.00) is the sum of materials (50.00), contract (60.00) and maintenance (20.00) costs, while the total cost of the bottom line (Reemay sleeves plus a support shaft = 163.00) represents the adjusted sum of materials (50.00 + 18.00), contract (70.00) and maintenance (25.00) costs.

*** BGR was not tested in this study but has been included in the cost comparison because, if used properly, it is competitive in performance and cost. The high maintenance cost reflects the sum of contract and materials, since a complete reapplication would be necessary if a second seasons protection were desired.

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