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Seedling Protectors for Preventing Deer Browse

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Wieger Schaap
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Introduction

The success or failure of forest regeneration in western Oregon and Washington often depends on control of animal damage to young seedlings. Roughly one out of five reforestation failures in the Pacific Northwest can be attributed to animals (Black et al. 1969, 1979). Black et al. (1979) determined that animals damaged an average of 30% of all unprotected Douglas-fir seedlings each year on the 165 Coast Range plots studied. Browsing by deer and elk was by far the most common, accounting for more than two-thirds of the total damage. Our results, averaged over nearly 50 sites throughout western Oregon and Washington, show that the incidence of damage approaches 40% for Douglas-fir seedlings untreated with protectors or repellents. Consequently, it is not surprising that animal damage has been estimated to cost the timber industry several million dollars each year (Brodie et al. 1979).

Damage to planted seedlings by deer and elk usually occurs in one of two ways. First, terminal and primary laterals are browsed off, eliminating or severely retarding seasonal height growth (Campbell 1974). Second, fine roots can be broken as deer or elk jerk seedlings upward through the soil during browsing. The harsher the site, the greater the impact of browse damage on the seedling, and the less likely is survival. In contrast, seedlings on favorable sites are exposed to fewer climatic extremes and frequently resume normal growth as browsing pressure declines and the availability of alternative forage increases (DeYoe et al. 1985).

Methods for controlling browse damage include fencing, protectors (sometimes called physical barriers), repellents, habitat manipulation, silvicultural modifications, and hunting (Black and Hoover 1978, USDA Forest Service 1978, Campbell and Evans 1983). Because protectors pose no apparent threat to the environment, do not harm big game, nor exclude wildlife from prime habitat, their use is an environmentally desirable approach to browse control.

There are two types of seedling protectors: those that protect the entire seedling and those that protect only the terminal. The current protector "standard" is the Vexar® tube, made of rigid polypropylene mesh, which encompasses the entire seedling and does not affect terminal growth if properly applied (Campbell and Evans 1975, Borrecco 1976, Crough 1980). Vexar® tubes have the advantage of being very effective for multiple pest control, particularly when mountain beaver, mice, rabbits, or elk are present on the site. However, high material and labor costs have encouraged use of a variety of alternative materials, few of which have been adequately evaluated.

The purposes of this study were three-fold: (1) to field test the protectors currently available to determine if any were as effective as the Vexar® tube but less expensive, (2) to assess each protector's impact on seedling survival and phenology, and (3) to define the specific advantages and limitations of each protector.

Materials and Methods

Eight protectors (Fig. 1 and Table 1), commonly applied commercially for individual tree protection, were evaluated: total seedling protectors tested were Vexar® tubes, light and heavy Vexar® netting, and Reemay® sleeves; terminal protectors tested were paper and Reemay bud caps, Vexar® leader tubes, and No Nibbles®. Unprotected control trees were also evaluated. Incidence of browse damage, seedling height growth, mortality, phenology, and loss of protectors were recorded in the spring and fall. Data from one and sometimes two growing seasons were gathered.

Test plots were established on 10 widely varying plantation sites (Table 2 and Fig. 2) to allow for more reliable extrapolation of data and to account for site-related variables such as different herds and seedling growth conditions. To ensure that all treatments were evenly distributed over each study site, the cluster plot design was selected (W.S. Overton, unpublished[1]). Comparison of growth rates is influenced by the variation in mortality and terminal deformation that is associated with the treatments. Many of the environmental factors (including animals) that influence seedling survival and early growth performance are distributed in a high spatial resolution—they involve micro-site properties. An obvious strategy, therefore, is to associate all the treatments under study at the micro-site

[1] Overton, W.S. 1982. On the use of cluster design in the field study of regeneration performance. Department of Statistics, Oregon State University, Corvallis (unpublished).

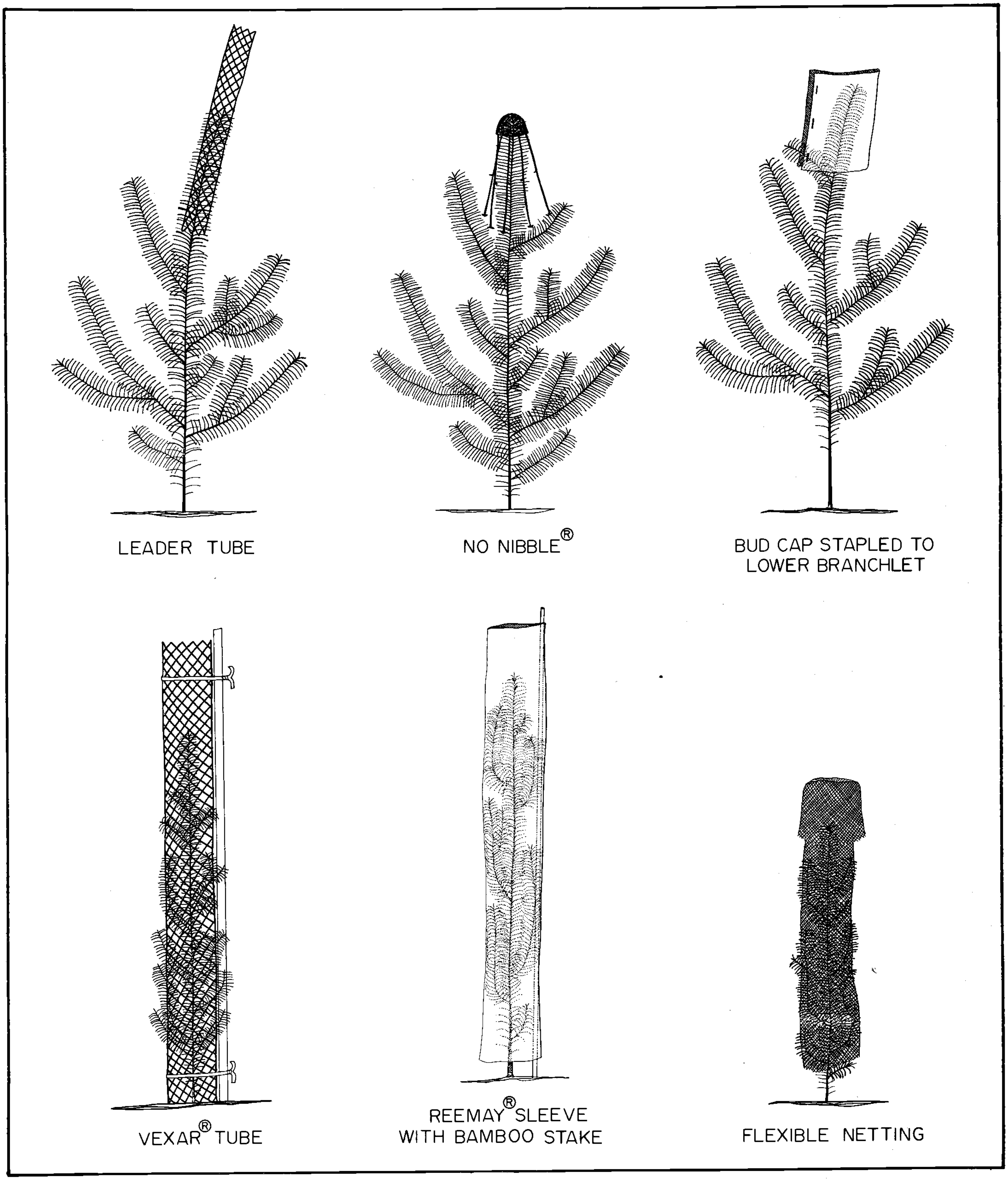

FIGURE 1.

VARIOUS PROTECTORS CURRENTLY AVAILABLE.

TABLE 1.

DESCRIPTION OF PROTECTORS USED.

Protector	Material	Dimensions[a]	Longevity[b]	Application technique
Vexar® tube	Rigid polypropylene mesh tube, large diamond pattern	30" tall by 3" in diameter	3–5 years[c]	The tube was slipped over the seedling and supported with wood lath or bamboo stakes.
Netting	Flimsy polypropylene mesh sleeve, small diamond pattern[d]	20 to 30" long (depending on seedling size) and about 2-1/2" in diameter	1–3 years	The netting was slipped over the seedlings, then one end was pulled to the base and stapled. The other end was extended 5–6" beyond the terminal bud, then folded back on itself to provide about 3" of protection for the leader. The netting was stretched slightly at the top to discourage leader entanglement.
Reemay® sleeve	Spun polyester sleeve[e]	28" tall by 2" in diameter	2–3 years	The sleeve was placed on PVC tubing which was slipped over the seedling and then pulled off, leaving the sleeve on the seedling. Depending on seedling size, the sleeve was stapled at the base (large), or a bamboo stake was inserted down through the sleeve and into the ground.
Bud cap				A bud cap, paper or Reemay®, was folded lengthwise around the terminal; it was then stapled along its lower portion so that it fit snugly. Ideally, the cap was stapled to a small lower branchlet. This approach normally required a cap at least 10" long.
Paper	Weatherproof paper	5"x8" sheet	6–18 months	
Reemay®	Spun polyester	4"x12–14" sheet	1–2 years	
Leader tube	Rigid polypropylene mesh tube, medium diamond pattern	24" long by 1-1/2" in diameter	2–4 years	The tube was slipped over the terminal leader and stapled to itself or to a lower insignificant branchlet.
No Nibbles®	Plastic	6" long with five thin fingergrips	1–2 years[f]	A No Nibbles® was placed over the terminal and the fingers collapsed around the stem.

[a] These dimensions apply to the listed materials as they are most commonly used in the field. Several alternatives are available for Vexar® tubes, leader tubes, and Reemay® sleeves and bud caps.
[b] The durability of a particular protector is largely dependent on its resistance to various environmental factors (wind, ultraviolet radiation, continual wetting and drying, freezing and thawing, etc.). The estimates presented normally reflect a range for extreme (short) to mild (longer) sites.
[c] The polypropylene material contains compounds which reflect high-energy UV radiation (Bill Bennett, International Reforestation Suppliers, Eugene, Oregon; personal communication).
[d] Two forms of netting were used: a light, 8-mil mesh and a heavier, 13-mil mesh.
[e] Reemay® is available in several thicknesses and can be cut to desired dimensions; these traits make it particularly desirable for use as bud caps.
[f] No Nibbles® were so susceptible to loss in moderate to high winds that few remained in place after a month. Terminal buds aborted on those that did remain.

level, in the form of a cluster of seedlings, one for each treatment. The comparison of growth performance is based, then, only on the pairs in which the seedlings from two different treatments survived and showed no terminal deformation. This comparison is a simple paired comparison over the comparable set and is repeated for each pair of treatments (see footnote 1).

Each of the 10 study sites consisted of three replications; each replication contained 20 cluster plots, each of which contained all the treatments tested on that particular site (only one protector per tree) (Fig. 1). The experimental unit and sampling unit was one seedling in a cluster plot.

T-tests for paired comparison were run ($\alpha \leq 0.05$) to test differences among the treatment means for height growth. Data on browsing, seedling mortality, protector loss, and restricted or bent terminals were analyzed with the chi-square (χ^2) test of independence ($\alpha \leq 0.05$). For these tests, each protector was tested against controls and Vexar® tubes.

TABLE 2.

DESCRIPTION OF STUDY SITES AND PROTECTORS TESTED.

Study site	Site characteristic															Protectors tested[c]
	Slope (%)	Aspect	Precipitation (in.)		Temperature (growing season) (°F)	Length of growing season[a] (days)	Prevailing winds			Soil type	Habitat	Cover			Elevation (ft)	
			Annual	Growing season			Winter	Summer	Intensity			Tree[b]	Shrub	Herb		
Morton	10–15	W	57[d]	2	50	180	SW	—	Med.	Silty/clay loam	—	DF, WF	berberie	—	1,580	LN, LT, RS, PBC
Butte Falls	15	NW, SW	50[e]	2	62	90	S	W	Low to med.	loamy (#34)	—	DF, WF	trailing black-berry, deerbrush	—	3,900–4,500	RS
Jewell	0	N–NW	75	18	65–70	150	S/SW	W/NW	High	clay/loam	converted pasture	—	—	orchard grass, bent grass	500	PBC, NN, LN, RBC, HN
Glide	10–40	NE	51	5	56	150	W/SW	SW	Med.	loam/light clay loam	—	DF	black-berry	fireweed	2,700	PBC, RS, LT, LN, VT
Galice	60	N–NE	65	70	61	200	W/SW	SW/W	—	loam/sandy loam	—	DF	—	—	1,800	VT, LN, RS
Alsea	0–5	W	80	9	57	190	W/SW	NW	Med. to high	sandy loam	converted pasture	DF	red alder, bigleaf maple	oxalis	350	HN, PBC, RBC
Coos Bay	0–30	E	65	20	61	200	W/SW	NW	High	silt/loam	—	DF, WH	salmon-berry	—	$\leq$500	RS, VT, LN, RBC, HN
Gold Beach	12–30	SW, W	80	25	61	240	SW	NW	Med.	clay/loam	—	DF	Oregon myrtle	blue blossom	$\leq$500	LT, PBC, VT
North Umpqua	30	S	60[f]	12	60	90	SW	W/NW	High	rocky/clay	—	DF, WH	rhodo-dendron	—	4,700	VT, RS
Myrtle Point	0–7	—	65	20	61	200	W/SW	NW	Med. to high	silt/loam	—	DF	—	grass	$\leq$500	PBC, LT, LT + stake

[a] Beginning of budburst until cessation of diameter growth.
[b] DF = Douglas-fir, WF = white fir, WH = western hemlock. 2–0 Douglas-fir had been planted on all sites except Morton, which received DF 1–1, and Glide, which received a mix of DF 2–0 and DF 2–1.
[c] HN = heavy netting, LN = light netting, LT = leader tube, NN = No Nibbles®, PBC = paper bud cap, RBC = Reemay® bud cap, RS = Reemay® sleeve, VT = Vexar® tube.
[d] At Morton, 70% as snow.
[e] At Butte Falls, 60% as snow.
[f] At North Umpqua, 80% as snow.

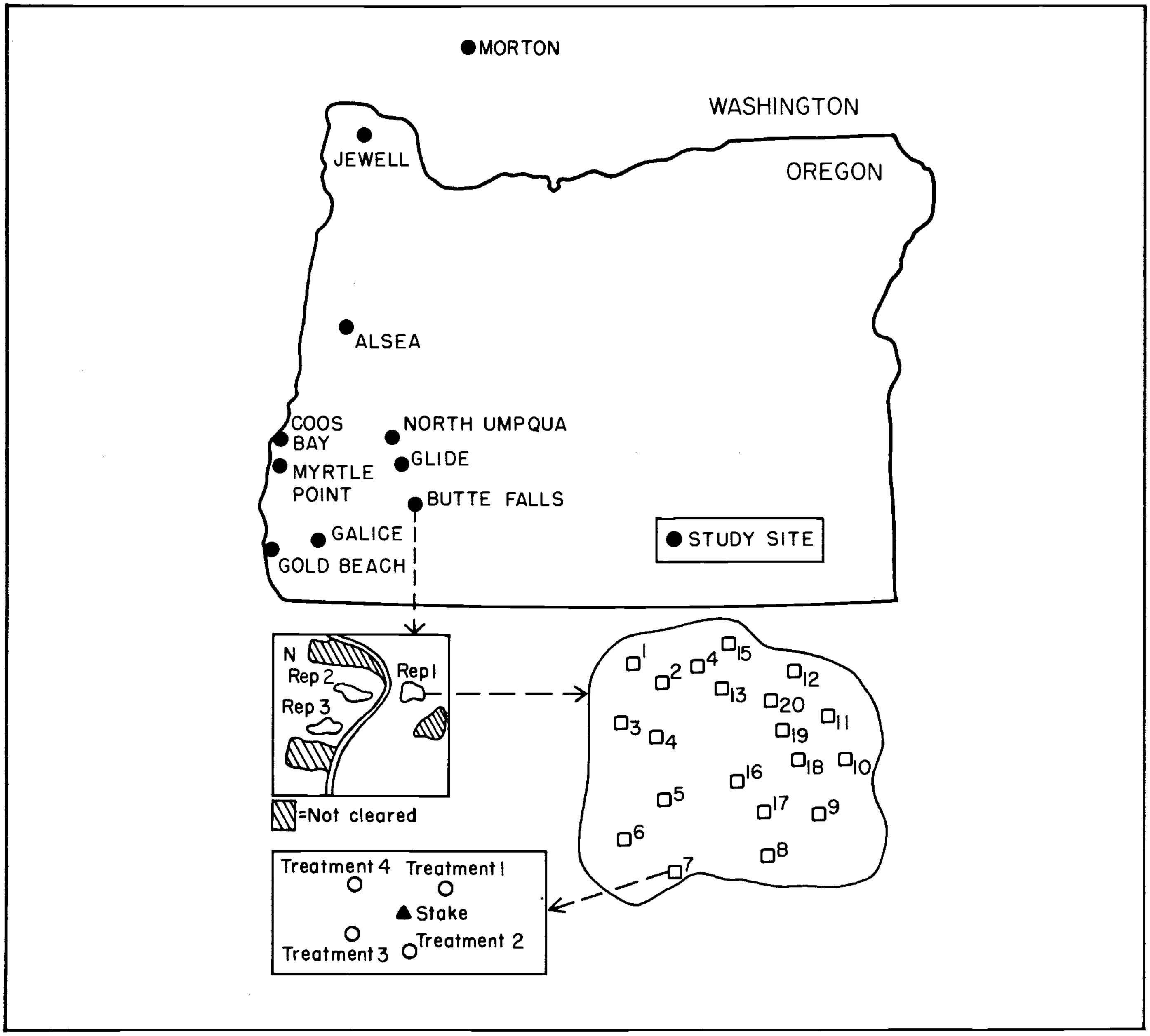

FIGURE 2.

EXPERIMENTAL DESIGN AND STUDY SITE LOCATIONS.

Results and Discussion

Browse, Mortality, Restriction, and Loss

Control Trees

All unprotected control trees were browsed to a significantly greater extent than trees with protectors (Table 3). This was true whether the site was subject to high (85%) or low (25%) browse intensity; overall browse damage by deer and elk averaged 39.5%.

Mortality of control trees was not significantly different from that of protected trees on most sites (Table 3).

TABLE 3.

PERCENTAGES OF TREES BROWSED, DEAD, WITH RESTRICTED OR BENT TERMINALS, OR WITH LOST PROTECTORS, BY TREATMENT AND SITE.

Treatment and site[a]	Browse (%)	Mortality (%)	Restricted terminal (%)	Protector loss (%)
Control				
Glide	4.7	0.0	—	—
Butte Falls (1)	—	8.3	—	—
Butte Falls (2)	—	26.6[b]	—	—
Jewell	28.0	—	—	—
Galice (1)	85.0	6.7	—	—
Galice (2)	36.7	10.0	—	—
Morton	25.5	—	—	—
Coos Bay (1)	35.6	—	—	—
Coos Bay (2)	51.1	0.0	—	—
Gold Beach	33.3	0.0	—	—
North Umpqua	—	6.0	—	—
Alsea	55.6	—	—	—
Myrtle Point	36.4	—	—	—
Treatment mean	39.5	7.2	—	—
Vexar® tube				
Glide	0.0	1.6	8.0	0.0
Galice (1)	0.0	1.7	—	—
Galice (2)	15.0[c]	3.3	11.7	—
Coos Bay (1)	6.7	—	2.2	17.8[d]
Coos Bay (2)	0.0	6.6	11.1	6.6
Gold Beach	0.0	2.4	2.4	9.5
North Umpqua	—	12.0	—	—
Treatment mean	3.6	4.6	7.1	8.5
Leader tube				
Glide	0.0	0.0	13.0	3.2
Morton	6.8	—	11.9	—
Gold Beach	0.0	0.0	12.0	7.1
Treatment mean	3.2	0.0	12.3	5.2
Paper bud cap				
Glide	0.0	0.0	0.0	0.0
Jewell	32.0[e]	—	18.0[f]	26.0[d]
Morton	1.7	—	1.7	—
Gold Beach	0.0	0.0	0.0	59.5
Alsea	0.0	—	6.7	—
Treatment mean	6.7	0.0	5.3	28.5

Treatment and site[a]	Browse (%)	Mortality (%)	Restricted terminal (%)	Protector loss (%)
Reemay® sleeve				
Glide	0.0	0.0	9.0	3.2
Butte Falls (1)	—	38.3[b]	25.0	—
Butte Falls (2)	—	58.3[b]	—	—
Galice (1)	0.0	11.7	—	—
Galice (2)	5.0	10.0	63.3[g]	—
Morton	0.0	—	13.6	—
Coos Bay (1)	0.0	—	44.4[g]	6.7
Coos Bay (2)	0.0	2.2	20.0[h]	11.1
North Umpqua	—	6.0	—	—
Treatment mean	1.0	10.1	29.2	7.0
Reemay® bud cap				
Jewell	24.0[e]	—	14.0	24.0[d]
Coos Bay (1)	2.2	—	2.2	8.9
Coos Bay (2)	2.2	0.0	8.9	22.0[d]
Alsea	0.0	—	13.4	—
Treatment mean	7.1	0.0	9.6	18.3
Light netting				
Jewell	16.0	—	12.0	8.0
Coos Bay (1)	6.7	—	24.4	8.9
Coos Bay (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	—
Treatment mean	5.6	3.6	35.3	7.9
Heavy netting				
Alsea	0.0	—	15.6	—
Jewell	12.0[e]	—	10.0	40.0
Coos Bay (1)	6.7	—	6.7	24.4
Coos Bay (2)	6.7	4.4	28.9	4.4
Treatment mean	6.5	4.4	15.2	22.9
No Nibbles®				
Jewell	32.0		28.0	48.0

[a] (1) = first year, (2) = second year.
[b] Harsh site.
[c] Leaders had elongated beyond the top of the tube.
[d] Protector loss due to strong winds.
[e] Occurrence of browsing after protector loss.
[f] Restricted terminals due to strong winds.
[g] Not staked.
[h] Staked second year—carryover effect.

Vexar® Tubes

Browse protection by Vexar® tubes was found to be very good: only 0–15% of the trees on any site were browsed. This was significantly less ($\alpha = 0.05$) than for control trees but not significantly different from other protectors. The 15% browse on the Galice site was of terminals extended beyond the top of the tubes.

Mortality was low on most sites (4.6% overall), and no significant differences occurred between trees protected by Vexar® tubes and other protectors or control trees. However, on the North Umpqua site, mortality of trees protected by Vexar® tubes was assessed as moderate (12%). This mortality may have been caused by root damage due to improper stake placement during installation of the tubes, because it was observed only on one site and good survival of controls suggests stock quality was satisfactory.

The occurrence of restricted terminals was significantly less for trees protected by Vexar® tubes than for trees with other protectors (Table 3). 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 become entangled or bend downward, escape through the side, or abort, especially with small seedlings or on sites with strong winds.

The loss of Vexar® tubes (due to winds, removal by animals, etc.) was low, averaging 8.5% overall (Table 3). The 17.3% loss on the Coos Bay site was due to strong winds.

Light and Heavy Netting

Overall protection against deer browse by both light netting and heavy netting was found to be good (4.9 and 8.5%, respectively), and significantly less than for control trees. There was no significant difference between protection provided by flexible netting and that provided by other means.

Mortality for trees protected by light netting and heavy netting was low, averaging 3.6 and 4.4%, respectively. This mortality was not significantly different from that associated with other protectors or control trees.

Restriction or bending of the terminal was found to be less troublesome with heavy (15.2%) than with light netting (35.3%) but was still considered moderate. In many cases the terminal penetrated through the side, or moderate to strong winds appeared to flip the netting over the elongating shoot, negating efforts to ensure correct application.

The problem of terminal distortion can be avoided for small, fully protected seedlings by using three bamboo stakes to spread the netting far enough apart to prevent terminal hang-up. Netting was installed with three stakes on the Galice site the first year; no terminals became restricted. However, while the netting was being adjusted for the second growing season, two of the three stakes were removed, resulting in a high rate of restricted terminals (65%). Successful terminal release can best be achieved by not allowing the netting to extend more than 3 inches beyond the terminal at installation. As the terminal grows, the netting can be adjusted by pulling the bottom up and over itself, which is less damaging to newly flushing laterals than pulling from the top.

Overall, protector loss was low to moderate for light netting (7.9% overall) and high for heavy netting (22.9% overall). Loss can be reduced by stapling the netting to small, insignificant lower branchlets.

Reemay® Sleeves

Browse protection by Reemay® sleeves was very good: only 1% (overall) of the trees were browsed. This browsing occurred only when terminals escaped through the top or when laterals escaped through the side after deterioration of the sleeves. To prevent browsing after terminal escape, the sleeve can be carefully adjusted upward or a repellent can be applied to the leader.

When Reemay® sleeves were used properly and on the right site, mortality of trees with such protection was not significantly different from that of trees protected by other means or control trees. However, Reemay® sleeves of the dimensions used in this study had an adverse effect on seedling survival on the Butte Falls site: mortality reached 38.3% the first year and 58.3% the second year. This high mortality rate coincided with a heat spell in August 1981 and 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 apparently prevented adequate dissipation of sensible (convection) and latent (vaporization) heat, which could have contributed to overheating and tissue injury. This problem may have been compounded by the "greenhouse effect" (excessively high CO_2 concentrations), which can signal stomatal closure and limit transpirational cooling. Vexar® tubes and netting have also been shown to increase mortality on xeric sites (Harry Hartwell, Washington Department of Natural Resources, personal communication). The risk of mortality resulting from buildup of heat and CO_2 concentrations increases with all types of total seedling protectors that cause bunching of 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 (plugs or 2–0s), a terminal protector should be supported with a lath or bamboo stake, and flexible netting should be spread with three bamboo stakes. 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 should still be used on xeric sites with high solarization potential.

Reemay® sleeves, when allowed to flop without support, caused terminals of smaller seedlings to bend and become contorted within the sleeve. Such contortion was also observed when the drooping sleeve became snagged by adjacent brush. There are three ways to avoid this problem: (1) insert an arrow shaft or bamboo stake down through the sleeve; (2) cut off the sleeve 4–8 inches (10–20 cm) above the terminal bud and return later to adjust the sleeve as the terminal protrudes; and (3) use sleeves only 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 or bending of 44.4% of the terminals. Trailing blackberry vines snagging the drooping sleeve tips appeared responsible, in part, for this high level of terminal interference. The sleeves were supported with bamboo prior to the second growing season. Half (24.4%) of the terminals, restricted or bent the previous year, straightened out; the remaining 20% did not straighten, and no new bending of terminals was observed. If sleeves had been supported from the beginning, terminal restriction would have been prevented.

Larger seedlings (big 2-1's or annually browsed, well-established seedling "bushes") are generally able to grow up through the sleeves without support, if snagging does not occur. Such growth 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.

Sleeve loss was low (7.0% overall). Loss can be reduced by stapling the sleeve together at the base of small seedlings, or on large seedlings by stapling it to a small lateral branchlet if it is to be used as a drooping bud cap.

Paper Bud Caps

Paper bud caps were very effective in preventing browse damage: only 6.7% (overall) of the trees with such protection were browsed. Strong winds on the Jewell site were responsible for protector loss, which left unprotected trees susceptible to browsing (32%). If the Jewell site is deleted, overall browse damage was less than 1%. Browsing can occur after the terminal emerges from the end of the cap. The cap should not be adjusted upward early in the growing season because the young shoot is not strong enough to support the weight of the cap. If damage is expected, the terminal should be treated with a repellent.

No mortality was observed for trees protected by paper bud caps. However, heat damage to young terminals was observed in a few instances (less than 5%), which suggests a potential hazard on hot, dry sites with southwest aspects.

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

The loss of paper bud caps was found to be very high (28.5% overall). Loss increased with increasing wind velocity and the occurrence of wind eddies. Protector loss can be decreased by stapling 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.

Reemay® Bud Caps

Reemay® bud caps performed well in protecting seedlings against deer browsing (7.1% browsed). However, if bud caps were not securely attached, loss during strong winds made trees susceptible to browsing.

No seedling mortality was observed. However, there was occasional damage (less than 5%) to terminals by spot heating.

The occurrence of restricted or bent terminals was low with Reemay® bud caps (9.6% overall).

Loss of Reemay® bud caps was found to be moderate to high (18.3% overall), especially on sites with strong winds. Again, the incidence of protector loss can be minimized by stapling the bud cap to a small branchlet.

Leader Tubes

Deer browse on trees protected by leader tubes averaged 3.2% on the three sites where this device was tested. There was no mortality of trees protected by leader tubes.

The occurrence of restricted or bent terminals was found to be moderate when leader tubes were used. However, leader tubes were only used on larger, well-established seedlings. Although leader tubes can be used on smaller seedlings, modifications to accommodate their weight (use of arrow shaft for support) would be needed. Minimizing terminal restriction 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 (Fig. 1). This would also lessen the chance of terminal entanglement from wind effects.

Protector loss was low when leader tubes were used (5.2% overall). Stapling the leader tube to a lower branchlet was responsible for minimizing protector loss.

No Nibbles®

It was hoped that these conical caps would not interfere with apical growth and simply be pushed

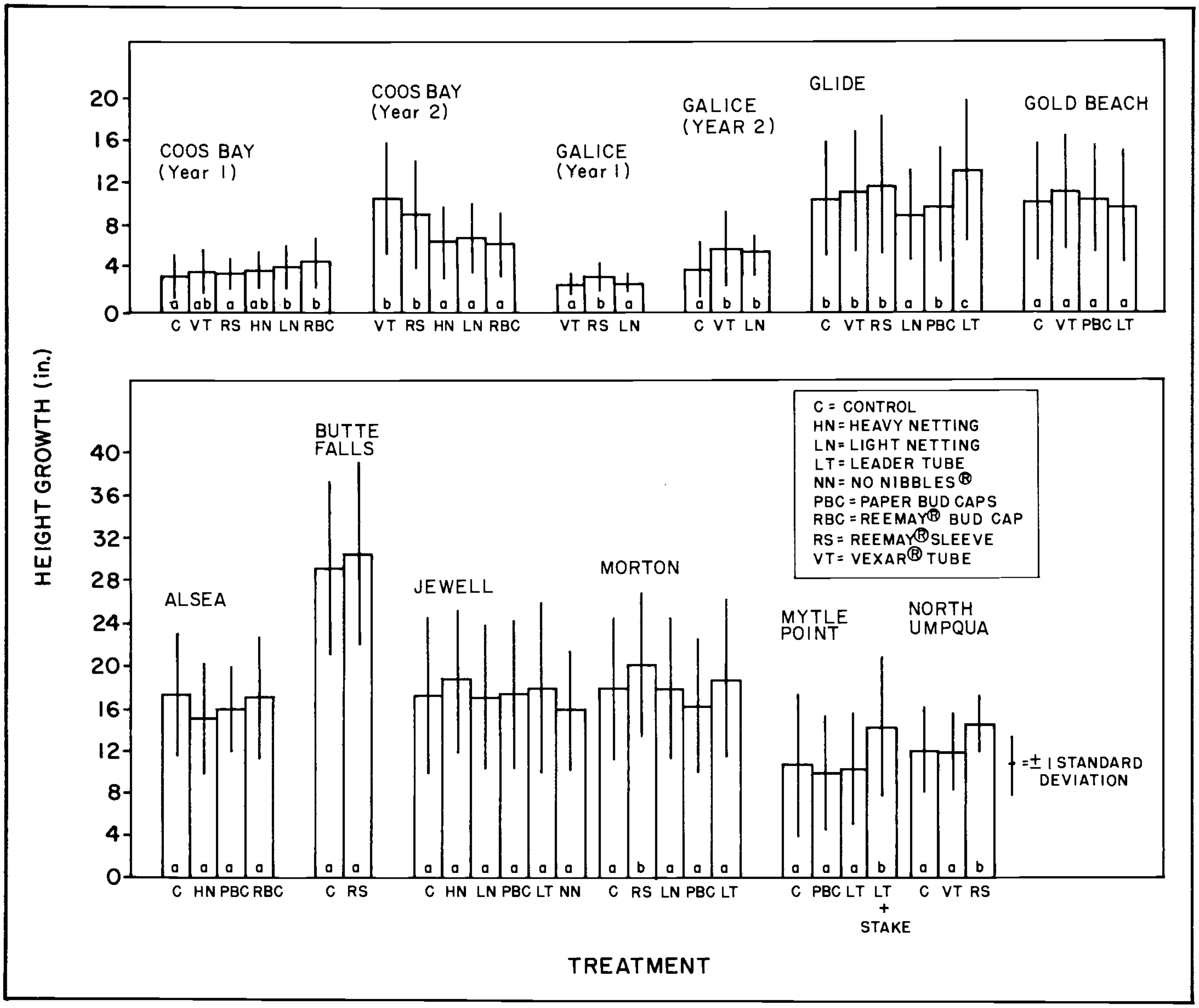

FIGURE 3.

HEIGHT GROWTH AT EACH SITE WHEN DIFFERENT TREATMENTS WERE COMPARED. TREES WITH BENT OR RESTRICTED TERMINAL OR WITH PROTECTOR LOSS WERE EXCLUDED FROM THE ANALYSES. FOR EACH SITE, BARS LABELED WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT AT $\alpha \leq 0.05$ ACCORDING TO THE T-TEST FOR PAIRED COMPARISONS.

upward as the leader extended. Unfortunately, the apical meristems in Douglas-fir seedlings are very sensitive to pressure. Even these lightweight caps exerted enough force to reduce extension growth and, on many trees, caused death of the terminal bud. No Nibbles® were also highly susceptible to loss by wind. Although No Nibbles® were not tested on sites other than Jewell, the high incidence of terminal abortion on seedlings retaining the No Nibbles® suggests that this device should not be used with Douglas-fir.

Height Growth

In general, height growth was not adversely affected by any protector (Fig. 3). In fact, when compared to unbrowsed control trees on some sites, trees had significantly better growth when protected by Vexar® tubes (Galice, 34% more), Reemay® sleeves (Morton, 15% more; North Umpqua, 17% more), light netting (Galice, 18% more; Coos Bay, 45% more), leader tubes (Glide, 26% more), and Reemay® bud caps (Coos Bay first year, 55% more).

When compared to trees protected by Vexar® tubes, trees with other protectors sometimes grew significantly more and at other times grew significantly less. For example, at the Coos Bay site the second year, trees with light and heavy netting and Reemay® bud caps grew significantly less (41, 42, and 52%, respectively) than trees with Vexar® tubes. At the Glide site, height growth of trees protected by leader tubes was significantly greater (21% more) than that for trees protected by Vexar® tubes. Trees with Reemay® sleeves also grew better (16% more) than those with Vexar® tubes on the Galice (first year) and North Umpqua sites.

Costs

Table 4 lists the costs associated with the different protectors. Total cost is given as the sum of costs for materials, contracts (administration + labor), and maintenance. The figures are averages of costs for contracts administered by the U.S. Forest Service, private industry, and small woodland owners (DeYoe et al. 1985).

TABLE 4.

COMPARATIVE COSTS OF USING VARIOUS PROTECTORS AGAINST DEER BROWSE.

Protector	$/acre (500 seedlings) Mater-ial[a]	Con-tracts[b]	Mainte-nance[c]	Total
Vexar® tubes with lathe stakes	150	80	35	265
Reemay® sleeves (3-foot length)[d]	45	60	20	125
plus 1 bamboo support stake	63	70	25	158
Heavy netting (2-foot length)	31	45	25	101
plus 3 support stakes	85	75	30	190
Light netting (2-foot length	10	45	25	80
plus 3 support stakes	64	75	30	169
Paper bud caps	12	40	25	77
Reemay® bud caps	7	40	20	67
Leader tubes (2-foot length)	50	60	25	135
plus 1 support stake	68	70	30	168

[a] The cost of all materials needed for adequate deer browse protection. These costs can be reduced 10 to 25% if one buys in bulk.
[b] Costs associated with hiring a crew to install or apply the respective protectors.
[c] The cost of assessing the need for maintenance (plantation survey) and making the necessary adjustments. It does not include replacement costs of lost or destroyed materials.
[d] This line (Reemay® sleeves alone = $125) is the sum of material ($45 for 3-1/4" x 3' sleeve), contract ($60), and maintenance ($20) costs. The next line (Reemay® sleeves plus a bamboo support stake = $158) represents the adjusted sum of material ($45 + $18), contract ($70), and maintenance ($25) costs. The same procedure is followed for other alternatives when support stake costs are listed.

Conclusions

From this study, several conclusions can be drawn that can help in the selection and effectiveness of a seedling protector.

1. There are alternatives available at lower cost than Vexar® tubes and stakes, and with comparable effectiveness.
2. All eight protectors effectively prevented browse damage (average less than 5%).[2]

[2] Recently, a deer repellent study, conducted on 33 sites ranging from southern Oregon to the Olympic Peninsula on the west side of the Cascades, showed average browse damage, over all sites, to be 40%. The best chemical alternative in that study was a powdered formulation of Big Game Repellent (Deer Away®), which kept browse damage below 10%, if properly applied (D.R. DeYoe and W. Schaap, manuscript in preparation).

3. Protectors rarely affected seedling survival.

4. Deformation of the terminal was increased on some, but not all, sites by flexible netting, Reemay® sleeves, leader tubes, No Nibbles®, and Vexar® tubes; however, support shafts, when properly used, can minimize or even eliminate terminal deformation.

5. Wind caused a greater loss of terminal protectors than of total seedling protectors.

6. Height growth was not adversely affected by any protector.

7. Restricted terminals and protector loss can be decreased by proper staking and stapling, respectively.

Variability of the results from plot to plot indicates that success with a particular device may depend on such site characteristics as 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 deer populations. Consequently, it would be to the advantage of silviculturists to compare the effectiveness of the various protectors in their areas of responsibility, especially if sites differ markedly from our test sites.

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The study compares the efficacy of eight protectors for minimizing deer browse: Vexar® tubes, heavy netting, light netting, Reemay® sleeves, paper bud caps, Reemay® budcaps, leader tubes, and No Nibbles®. Data were collected on browse damage, survival, terminal restriction, protector loss, and height growth. All protectors were effective in preventing browse damage. None of the protectors consistently reduced survival or height growth. However, on a high-elevation (4,500-foot) site facing southwest, seedlings inside Reemay® sleeves survived poorly compared to controls following a week of daytime temperatures above 100°F. Restricted or bent seedling terminals and protector loss occurred with certain protectors on some sites; however, these problems could be decreased by proper or modified installation with stakes or stapling, respectively. Only No Nibbles® caused abortion of terminal bud flushes. The study demonstrates that alternatives to Vexar® tubes are available that cost less and exhibit comparable effectiveness.

KEY WORDS: height growth, physical barriers, seedling mortality, seedling protector, terminal restriction.

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