"VEXAR"[1] PLASTIC NETTING TO REDUCE POCKET GOPHER DEPREDATION OF CONIFER SEEDLINGS

RICHARD M. ANTHONY and VICTOR G. BARNES, JR., U.S. Fish and Wildlife Service, Silviculture Laboratory, Bend, Oregon 97701
JAMES EVANS, U.S. Fish and Wildlife Service, Forestry Sciences Laboratory, Olympia, Washington 98502

ABSTRACT: In 1976, we began a comprehensive evaluation of "Vexar" seedling protectors as a means of reducing damage to conifer seedlings by pocket gophers (Thomomys spp.). The protectors are cylinders of plastic netting that gradually decompose in sunlight. The evaluation is being conducted on four national forests in three western states. Three conifer species, lodgepole pine (Pinus contorta), ponderosa pine (P. ponderosa), and Shasta red fir (Abies magnifica var. shastensis), are under study. After two growing seasons, gophers have caused only 5 percent mortality among "Vexar"-enclosed seedlings compared to 20 percent mortality among unprotected seedlings. In addition, stocking and heights of protected seedlings are better than those of unprotected seedlings. Problems associated with the use of "Vexar" included compression of the protectors by snow, breakage of the plastic during subfreezing temperatures, and protrusion of seedling terminals through mesh openings; however, these problems have been minor thus far. Information on long-term effectiveness and cost efficiency is still needed before we can recommend operational use of "Vexar" protectors for pocket gopher damage control.

INTRODUCTION

Damage to planted conifers by pocket gophers (Thomomys spp.) is a major concern of forest managers in western United States. Gophers damage conifers at almost all stages of stand development, but most severe damage generally occurs during early regeneration, principally from gophers cutting or gnawing off roots and main stems of seedlings. This commonly results in seedling mortality and eventual understocking, or suppressed seedling height growth and regeneration delay. Reducing damage during the first few years after planting minimizes this effect.

Recognition of the impact of pocket gophers on forest management has increased dramatically during the past few years. In 1970, gopher damage was recognized as a problem affecting ponderosa pine (Pinus ponderosa) and lodgepole pine (P. contorta) plantations, primarily in eastern Oregon and Washington (Barnes, 1973). Today, gopher damage is considered a principal factor limiting reforestation of pine, fir (Abies spp.), and other conifers on over 120,000 ha of forest land (Northwest Forest Pocket Gopher Committee, 1976; Patee, U.S. Forest Service, personal communications, 1976); this damage causes millions of dollar's loss of potential timber. Because of a large backlog of land in need of reforestation and the increasing demands for wood products, prompt conifer regeneration has acquired high priority and pocket gophers are likely to remain an important reforestation problem in the foreseeable future.

Control methods presently available to land managers are aimed at population reduction and include trapping and machine- or hand-application of toxic grain baits; these methods, however, have not adequately reduced seedling losses because of limitations in operational programs and problems inherent to direct population control (Barnes, 1973; Northwest Forest Pocket Gopher Committee, 1976; Capp, 1976). Indirect population control by reducing abundance of required foods with herbicides (Black and Hooven, 1974; Borrecco, 1976) is a promising approach to the pocket gopher-reforestation problem, but current information has application in only a few forest communities.

The inadequacies of population control prompted us to consider mechanical protection as an alternate method of reducing gopher damage. Wire cages around individual seedlings have shown utility in deterring animals (Black et al., 1969), but caging was not a practical consideration until the development of "Vexar" plastic seedling protectors (Campbell and Evans, 1975). This paper reports on our evaluation of the "Vexar" protector as a mechanical device to reduce pocket gopher damage to conifer seedlings.

"VEXAR" SEEDLING PROTECTORS

"Vexar" seedling protectors were originally developed for reducing feeding injuries to Douglas-fir (Pseudotsuga menziesii) by lagomorphs and big game animals. The protector we are evaluating is a 76-cm long cylinder of photodegradable, polypropylene plastic netting with an inside diameter of 5 cm; mesh opening is 9 mm and strand diameter is 1.5 mm. This particular protector (DuPont code: 2-in ID 60-PDP-27, translucent green) was determined to be highly effective with negligible adverse effects on growth of Douglas-fir seedlings; effective life of this device is about 4 years. Decomposition is caused by ultraviolet radiation and there are no known environmental hazards associated with the plastic or its by-products (Campbell and Evans, 1975). In brief, "Vexar" seedling protectors are light weight, relatively durable and inexpensive, and therefore, attractive as barriers to forest animals.

[1]Registered trademark of E.I. DuPont de Nemours & Co., Inc. Reference to trade names does not imply U.S. Government endorsement of commercial products.

PRELIMINARY TRIALS

Although effectiveness of "Vexar" protectors had been demonstrated for other types of animal damage, our initial assessment of their potential for controlling gopher damage was discouraging. Previous workers (Howard, 1953; Connolly and Landstrom, 1969) had found that gophers could gnaw hard materials suchas metal-sheathed communication cable, and laboratory tests at our Denver Wildlife Research Center revealed that the animals could easily chew through "Vexar". However, in five pilot field tests conducted in central Oregon from 1973 to 1976, the seedling protectors were highly effective in reducing losses to gophers; when compared with unprotected seedlings, seedling mortality was reduced 88 percent (range 77% to 97%). These pilot tests provided other useful information, such as the need to protect both above- and below-ground portions of seedlings, and that "Vexar" tubes of rigid, diamond-shaped mesh design were more resistant to compression by snow than tubes of the lighter twill design described by Campbell and Evans (1975). We also were able to develop and refine techniques of packaging seedlings in "Vexar" and planting packaged seedlings. The promising results of those tests led us to conduct a comprehensive evaluation of "Vexar" seedling protectors.

EVALUATION

Study Areas

We decided to select study areas representative of forest types in which gophers most severely affect reforestation. Aided by personnel of the U.S. Forest Service, we located four areas--one each in northern California, central Oregon, southwestern Idaho, and eastern Idaho. Within each area we selected specific study sites based on past history of reforestation failure due to gophers, uniformity of gopher distribution, and homogeneity of vegetative composition and distribution. In northern California (Klamath National Forest) we established a study unit on three high-elevation (1800-m) clearcuts where Shasta red fir (*Abies magnifica* var. *shastensis*) seedlings were planted; each clearcut had been terraced to prepare the site for planting. In central Oregon (Deschutes National Forest) we chose a high-elevation (1700-m) lodgepole pine community with 4- to 8-ha clearcuts. Here, slash had been machine piled and burned prior to planting lodgepole pine. A third unit was located in a mixed-conifer forest in southwestern Idaho (Boise National Forest) where ponderosa pine seedlings were planted on large (12- to 16-ha), high-elevation (1700-m) clearcuts on which scalping with hoes was used for site preparation. The fourth unit was established in eastern Idaho (Targhee National Forest) on 12-ha clearcuts located in a high (1900-m) caldera occupied by lodgepole pine forests; here, lodgepole pine seedlings were planted in machine-scalped spots. Study units on the Boise, Deschutes, and Klamath National Forests were established in spring 1976; the unit on the Targhee National Forest was installed in spring 1977.

Design and Procedures

Individual study units are comprosed of four experimental replications, each containing four 0.4-ha sample blocks. On each block there are ten randomly located 40-m^2 subplots containing "Vexar"-protected seedlings and ten subplots containing unprotected seedlings. Every subplot contains four seedlings individually marked by a numbered wooden stake. This provides a sample of 640 protected seedlings and 640 unprotected seedlings per study unit, or a total of 2,560 sample seedlings of each kind for all study units. The sample comprised about 9 percent of all planted seedlings on the study sites.

In addition to the seedling subplots, we established twenty 81-m^2 circular subplots per replicate to measure pocket gopher activity. The amount of gopher sign (mounds, plugs, and casts) observed on these subplots provides a relative index of gopher abundance within each study unit. Stratified random sampling was used to insure that there were at least two subplots in each 0.4-ha block.

The need for complete enclosure of seedlings in "Vexar" protectors required "packaging" and planting packaged seedlings. Our procedure began with inserting the bare-root seedling in a solid plastic (polyvinyl chloride) pipe of slightly smaller diameter than the "Vexar" tube. This pipe acted as a protective carrier of the seedling during its insertion into the "Vexar" tube. After being positioned so that its lower roots were at the bottom of the "Vexar" tube, the seedling was held in place and the plastic pipe was removed (Fig. 1A). Moistened soil, taken from the vicinity of the planting site, was packed through the mesh around the roots of the seedling (Fig. 1B). Packaged seedlings were prepared in assembly-line fashion at a rate of about 80 seedlings per man-hour. Packaged seedlings were carried to the field in burlap bags and auger-planted (Fig. 1C).

Collection of data is done in May and September each year and is scheduled for 5 years from date of planting. During these examinations, we gather information on seedlings, protectors, and gopher activity. In spring, we inspect seedlings for damage and mortality, identify injury of seedlings by animal and nonanimal agents, and note both the extent of damage and its effect on the vitality of the seedlings. We also record the condition of the protector (e.g., damage and rate of decomposition) and any negative effects of the protector on seedling growth (e.g., constriction of branches and deformity of terminal stem). In September, we make the same observations and also measure height of all seedlings.

On gopher activity subplots, we record the presence or absence of winter "casts" in May; in September we count mounds and plugs made by gophers during a 48-hour period.

From these data we intend to quantify major elements affecting vitality, growth, and survival of all seedlings, and identify the adverse and beneficial effects of "Vexar".

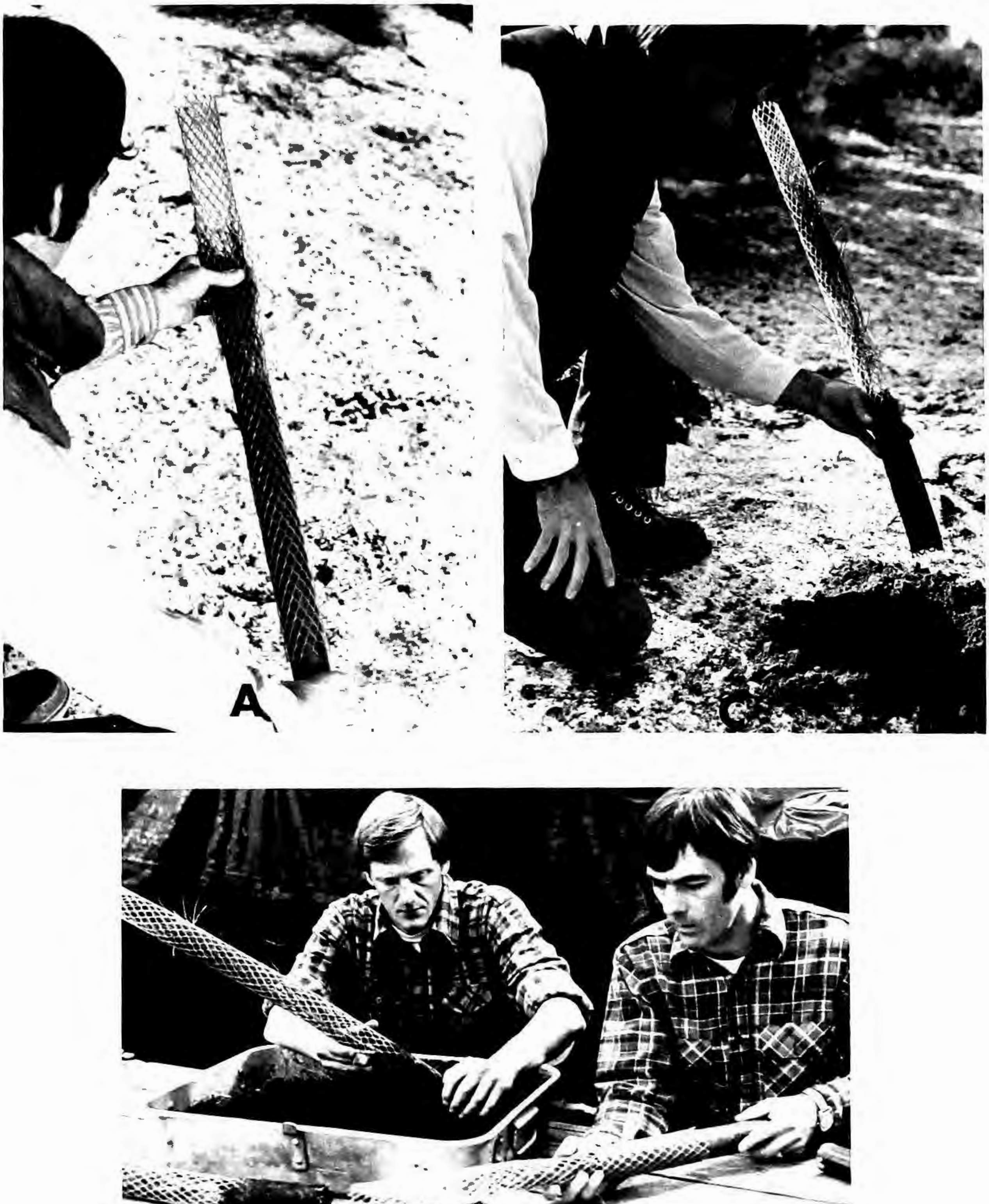

Figure 1. We inserted bare-root seedlings in "Vexar" protectors (A), packed moistened soil around roots (B), and transported packaged seedlings to the field for auger planting (C).

RESULTS

Data covering two growing seasons have been collected for the Boise, Deschutes, and Klamath study units; information from the Targhee unit has been only from the first growing season after planting. Therefore, comparisons of trends in survival, damage, and growth essentially concern the first three units. Unless otherwise indicated, analyses of data was by unpaired t-test for differences between treatment means within each study unit.

Seedling Survival and Damage

First-year seedling survival was impressive on all four study units. An average of 93 percent of the unprotected seedlings and 97 percent of the protected seedlings were alive the September following spring planting (Table 1); the difference in survival between treatments was primarily caused by early losses of unprotected seedlings to pocket gophers. By the end of the second growing season, survival of protected seedlings was significantly greater than that of unprotected seedlings on all three units for which data were available (Table 1). Overall, pocket gopher damage was the primary mortality factor of unprotected seedlings, accounting for 59 percent of the losses, and nonanimal mortality factors affected protected and unprotected seedlings equally.

Table 1. Survival (percent) of "Vexar"-protected and unprotected conifer seedlings after one and two growing seasons.

		Growing season			
		First-year survival*		Second-year survival*	
Study unit	Species	Unprotected	Protected	Unprotected	Protected
Boise	Ponderosa pine	95	98	91[a]	96[a]
Deschutes	Lodgepole pine	90	93	55[d]	84[d]
Klamath	Shasta red fir	89[b]	97[b]	51[c]	72[c]
Targhee	Lodgepole pine	97[c]	99[c]	--	--

*Figures with the same letter are significantly different at $(P<.05)^a$, $(P<.025)^b$, $(P<.005)^c$, or $(P<.001)^d$.

Percent seedling survival, particularly where gophers are a major influence, may not be as useful to forest managers as a measure of the distribution of surviving seedlings. This is because the distribution of gophers can be clumped (Hansen and Rummenga, 1961) and therefore cause an irregular occurrence of damage within plantations. Based on advice of silviculturists from the national forests involved in this study, we chose 500 seedlings per ha or two seedlings per 40-m^2 subplot as the minimum level of acceptable stocking. Using Chi-square test of independence, we found that more subplots with protected than unprotected seedlings ($P<0.05$) met this criterion. Percent of subplots adequately stocked after two growing seasons on respective study units were as follows: Boise (protected = 100%, unprotected = 97.5%); Deschutes (protected = 98.8%, unprotected = 69.4%); Klamath (protected = 85.6%, unprotected = 61.3%).

"Vexar" seedling protectors have effectively reduced gopher damage (mortality and injury) to planted conifers on each study unit (Table 2). Gopher-caused seedling damage was reduced 91 percent on the Boise, 93 percent on the Deschutes, and 62 percent on the Klamath. The relatively light gopher pressure on the Boise unit (only 11% gopher-caused seedling damage) might have been due to an apparent population decline--there were 80 percent fewer mounds counted in September 1977 than in September 1976. Gopher sign counts have indicated moderate and high populations, respectively, on the Deschutes and Klamath units, and these levels have been reflected in the amount of damage that has occurred on these units (Table 2).

Table 2. Gopher-caused damage (percent) of unprotected and protected seedlings at the end of the second growing season.*

	Mortality		Injury	
Study unit	Unprotected	Protected	Unprotected	Protected
Boise	7[b]	1[b]	4[b]	0[b]
Deschutes	21[d]	1[d]	5[c]	1[c]
Klamath	32[b]	13[b]	2[a]	<1[a]

*Figures with same letter are significantly different at $(P<.10)^a$, $(P<.025)^b$, $(P<.01)^c$, or $(P<.001)^d$.

Seedling Heights

Mean heights of protected seedlings exceeded those of unprotected seedlings at the end of the first and second growing seasons (Table 3). Differences were statistically significant for first-year measurements on the Boise, Klamath, and Targhee units and for second-year measurements on the Boise and Deschutes units.

Table 3. First- and second-year mean heights of surviving seedlings (centimeters).

	First-year height*		Second-year height*	
Study unit	Unprotected	Protected	Unprotected	Protected
Boise	19.6[b]	21.1[b]	22.9[d]	27.7[d]
Deschutes	22.7	23.6	22.7[a]	26.5[a]
Klamath	14.9[c]	17.8[c]	22.8	24.3
Targhee	16.7[d]	19.3[d]	--	--

*Figures with the same letter are significantly different at $(P<.10)^a$, $(P<.05)^b$, $(P<.025)^c$, or $(P<.001)^d$.

We recognize that several factors may have influenced seedling heights. To further define the role of these factors, we compared heights of undamaged seedlings. Nonlethal damage during the first growing season was negligible on all areas and seedling heights essentially were not affected. After two growing seasons, however, there was a significant difference ($P<0.10$) between treatments on the Boise and Deschutes units but not on the Klamath unit (Table 4).

Table 4. Second-year mean heights of undamaged seedlings (centimeters).

	Heights*	
Study units	Unprotected	Protected
Boise	23.2[b]	27.7[b]
Deschutes	24.5[a]	26.7[a]
Klamath	22.4	24.1

*Figures with the same letter are significantly different at $(P<.10)^a$, or $(P<.001)^b$.

Problems

The most notable problem associated with the "Vexar" protectors has been the deformity of seedling terminals that grow through the plastic mesh. On the Boise, Deschutes, and Klamath units, respectively, 0.8, 0.3, and 13.3 percent of protected seedlings have been affected. Another factor has been freezing temperatures which cause polypropylene plastic to become brittle and break when struck or bent. This cold breakage has occurred to 0.5, 4.7, and 1.9 percent of the tubes on the Boise, Deschutes, and Klamath units. An accordian-like compression of protectors by snow also has been noted. In May 1977, 4.2 and 24.8 percent of the protectors were compressed or bent on the Deschutes and Klamath units, respectively; however, by the following September only a few of these tubes showed signs of snow compression. We speculated that warm summer temperatures made the plastic pliable, allowing the tubes to return to their original shape. Snow damage was not observed on the Boise unit where snow accumulation during the 1976-77 winter was light.

DISCUSSION AND CONCLUSIONS

So far in this study, "Vexar" seedling protectors have substantially reduced conifer damage by gophers. The protectors have not reduced seedling losses to nonanimal damage factors such as drought, poor seedling vitality at planting, and poor planting conditions.

In addition to improving seedling survival, "Vexar" protectors appear to have beneficially affected seedling heights on the Boise and Deschutes units. Probably the most important factor contributing to height differences at the end of the second growing season (Table 3) was that unprotected seedlings sustained more gopher-caused injury than did protected seedlings (Table 2). Because most gopher damage occurred near ground level, mean heights of unprotected seedlings were markedly reduced. On the Klamath unit, heights of protected and unprotected seedlings did not differ significantly, probably because of a low incidence of injury and a relatively high occurrence of terminal deformity among protected seedlings.

Gophers may not be the only factor influencing heights of protected seedlings. Comparisons of undamaged seedlings after two growing seasons showed that mean heights of protected seedlings still were greater than for unprotected seedlings. Borrecco (1976) made similar observations studying Douglas-fir and hypothesized that stem movement from wind, which inhibits height growth (Neel and Harris, 1970), is reduced inside the protector. Another possibility is that the protectors provide a beneficial shading affect. Regardless of the cause, the possibility that "Vexar" protectors promote growth deserves further attention.

Anyone considering the use of "Vexar" protectors for gopher damage control should weigh a number of factors, including cold breakage, terminal deformity, snow compression, and cost; the relative importance of these factors should be evaluated according to the specific conditions of each damage situation. For example, cold breakage of seedlings has occurred infrequently in our study. Nevertheless, an awareness of critical temperatures and careful handling will be necessary to avoid the problem during operational planting. Furthermore, tube breakage could be a serious problem on plantations that incur heavy use by big game or livestock during subfreezing temperatures. Snow compression is another problem that could be expected to vary in importance according to local conditions.

Earlier studies of "Vexar" protectors indicated that protrusion of terminal stems of Douglas-fir was of minor consequence (Campbell and Evans, 1975; Borrecco, 1976); however, terminal protrusion might vary among and between conifer species. In our study, terminal deformity was negligible in lodgepole and ponderosa pine but common in red fir. Because red fir seedlings tend to develop multiple terminals, the ultimate effect on seedling growth may be less than our current data indicate.

Users should consider other potential difficulties which we have not observed in our study. Borrecco (Weyerhaeuser Company, unpublished data), for example, found that "Vexar" protectors were highly susceptible to frost heave on a pumice soil site in south central Oregon; many seedlings were lifted entirely out of the ground. Perhaps a more far-reaching concern is the possibility that, without exposure to sunlight, buried portions of "Vexar" might degrade too slowly and cause root constriction. Ellis (1972), using seedling containers with thicker plastic and more dense mesh pattern than that of our "Vexar" protectors, noted constricted roots of hardwood seedlings. However, Campbell (U.S. Fish and Wildlife Service, unpublished data) observed that the roots of 7-year-old Douglas-fir trees grew through mesh openings and engulfed the strands of "Vexar" protectors. These reports demonstrate that the question of root constriction must be answered conclusively before large-scale operational use of protectors for gopher damage control can be considered.

Economics probably will be one of the foremost concerns of many forest managers when contemplating use of plastic protectors. Using our packaging technique, the cost of planting protected seedlings would be two to three times that of planting bare-root seedlings. These costs certainly could be lowered with improvements in the preparation, transportation, and planting of enclosed seedlings, or perhaps by using containerized seedlings that could be inserted into protectors at the planting site. Still, cost will be high even with improved technology.

This added expense should be weighed against benefits of using "Vexar" protectors. Besides the reduction in damage and apparent height gains demonstrated in our study, "Vexar" protectors have been shown effective against other animals (Campbell and Evans, 1975; McPhee, 1975; Borrecco, 1976), some of which interact in gopher damage areas. On some areas, then, use of protectors could preclude the need for several different control measures. Moreover, installation of protectors generally would require just one commitment of labor (at planting time) whereas other available control measures usually involve several commitments and exact timing. Baiting, for example, must be done periodically for several years and requires suitable soil moisture conditions. Hence, when using "Vexar", both control efficacy and efficiency should be scrutinized.

Present information concerning the potential of "Vexar" seedling protectors for controlling conifer damage by gophers is encouraging. However, it would be premature for us to endorse large-scale use of seedling protectors prior to collecting more definitive information on efficacy, limitations, and operational application.

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