U. S. FOREST SERVICE
Research Paper PNW-6

About This File:
This file was created by scanning the printed publication.
Misscans identified by the software have been corrected;
however, some mistakes may remain.

PROTECTING FOREST TREES and their SEED from Wild Mammals

(A review of the literature)

by M. A. Radwan

DECEMBER 1963

PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
Philip A. Briegleb, Director
Portland, Oregon

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

CONTENTS

	Page
INTRODUCTION	1
MEANS OF PROTECTION	1
Reduction of Mammal Populations	1
Biological	1
Trapping and Shooting	2
Poison Baits	2
Contact and Systemic Poisons	3
Manipulation and Exclusion of Mammals	5
Cultural	5
Mechanical	6
Systemic and Contact Repellents	6
Area Repellents	8
CONCLUSION	9
LITERATURE REFERENCES	10
APPENDIX	24
Supplementary Information on Some Repellent Chemicals	24
Some Animals Causing Damage to Forest Resources	25
Summary of Reported Wild Mammal Damage	26

INTRODUCTION

An extensive literature points to wild mammals as agents that may seriously reduce the pro-
:tive capacity of forests and, in many ways, interfere with efforts to grow valuable trees. While
s loss of forest values is not a new problem, it has been brought into sharper focus through
ter identification of the various kinds of mammal-caused injuries and by improved survey tech-
ues. These latter actions have been spurred by the high values now attached to forest products
| consequent emphasis on early regeneration of timber stands.

Mammals may attack various parts of the plant at different stages of its development to pro-
e injuries differentiated in type, intensity, and effect on growth and development. Wild mammals
' also prefer certain plant species and even certain individuals of a species *(68)*. Limited in-
tigation, however, has not linked animal preference to such tree properties as succulence *(111)*
:ontent of protein *(26)*, vitamin *(171)*, or phosphorus *(59)*.

Wild mammals which cause damage to trees and create problems for the forest manager range
ize from the tiny shrew to the gigantic elk. A number of wild mammals known to cause damage
listed in the appendix.

Most injury to forest trees comes from animal feeding activities, resulting in seed destruction,
; severing, browsing, clipping, bud nipping, seedling pulling, tree cutting, and debarking. Other
ries, mainly trampling and rubbing, are caused by movements of large animals.[1]

Effective control measures must be devised to combat destructive mammals if adequate forest
uction is to be achieved. Although progress has been made in recent years toward improving
ɜction measures, the amount of forestry research on wild mammal control is still inadequate.

This paper summarizes some published research on the control of wild mammal damage to
ɜt trees.[2]

MEANS OF PROTECTION

Reduction of Mammal Populations

›logical

Predators.—Protecting and introducing predators has been suggested by some investigators
146) as a means of reducing rodent densities and damage to seeds and seedlings. Howard*(78)*,
›ver, pointed out that predators are of little significance in regulating rodent densities. He
›ves that rodents control predator populations, rather than the reverse.

)iseases.—Introducing a disease among problem mammals as a method of control has been
'antly considered because of the conflict in general acceptance of a given animal as a pest,
led with the possibility that introduced diseases may spread to game animals. The method,

Reported types of wild mammal damage to forest trees, motivation therefor, the animal responsible, and references
rature are contained in the appendix.

The survey of literature was completed in December 1961.

·ver, was successfully utilized in Australia *(67, 125)* by releasing the myxoma virus, the causa-agent of a disease called myxomatosis, to control the European rabbit *(Oryctolagus cuniculus)*.

Chemosterilants.—In recent years, entomologists and bird-control specialists have recognized ɪalue of chemosterilants. Investigations with chemicals that induce sterility in insects and ; are now in progress. Toxic agents that would reduce the population are mixed with chemo-lants that would destroy the reproductive ability of the survivors. This principle has never used in forestry in the control of wild mammals, and its evaluation would be highly desirable.

ıpping and Shooting

Trapping or shooting can be used to reduce the population of large mammals, but these methods mpractical for the control of small rodents in forests *(91, 146)*. Hunting and trapping are both to control bear in western Washington *(102)*, and hunting to control porcupines is practiced igh-damage areas in the ponderosa pine region. The value of legal hunting of deer and elk also been generally recognized. Many foresters recommend its intensification *(2)*, especially oung plantations *(91)*.

ison Baits

Seeds, fruits, or roots formulated into poison baits with strychnine, zinc phosphide, compound ,[3] warfarin,[4] thallous sulfate, tetramethylenedisulphotetramine (tetramine),[5] sodium arsenite, ɔme other rodenticide have proven useful or have shown promise of becoming useful as a prac-means of controlling some forest rodents. Investigators have recommended various formula-ɪ of poison baits to control meadow mouse *(81)*, wood rat *(76, 115)*, mountain beaver *(135)*, ɪet gopher *(45)*, hare *(14)*, and porcupine *(47)*.

Much of the literature on the subject deals with attempts to control seed-eating mammals. cer and Kverno *(151)* reported some success with tetramine. In the Douglas-fir region, the two commonly used poisons are compound 1080 and thallous sulfate applied to wheat or hulled lower seed. However, this treatment is not recommended for seeds with intact, inedible hulls use rodents usually cut through poisoned hulls and eat seed contents without being appre-ly poisoned.

Compound 1080 gave good initial rodent control when used alone *(52,72,116,161)* or in com-tion with thallous sulfate *(11)*, but the hazard of secondary poisoning from this compound, ɔared with that from thallous sulfate, limits its use. Baiting with seed treated with thallous ɪte controlled seed-eating rodents sufficiently to produce satisfactory stocking in both natural and artificial *(138)* seeding programs. This method, however, gives only very short periods ɔntrol because of rapid reinfestation from untreated areas *(146)*. With current poison bait con-methods, rebaiting is often practiced unless buffer strips are included in the initial baiting ation *(11, 72)*.

[3] Sodium fluoroacetate.

[4] 3-(alpha-acetonylbenzyl)-4-hydroxycoumarin.

[5] 2,6-dithia-1,3,5,7-tetrazatricyclo (3.3.1.1.^{3,7}) decane-2,2,6,6-tetraoxide. See Appendix for additional information.

:ontact and Systemic Poisons

In recent years, the trend in protecting seed and seedlings from wild mammals has been toward ıe use of poisonous and repellent chemicals applied to the tree or seed. Poisonous chemicals ·e of two general types: "contact," those which remain on the surface of treated plants, and systemic," those which are absorbed and translocated by the plant. Contact poisons do not pro- de protection to new shoots produced after the plant has been treated. A systemic poison, on e other hand, should be effective on the whole plant, including all new growth produced for some me after treatment.

Tetramine.—In 1951, the Denver Wildlife Research Laboratory introduced tetramine for treating ıniferous seed. Experiments showed the chemical to be nonphytotoxic, stable *(94)*, and very ıaringly soluble. In laboratory tests, treatment of seed with this highly toxic chemical was found extend protection from rodents to newly formed seedlings with no harmful effects to form or owth rate *(150, 151)*. First field trials on seed treated with a 1-percent solution of tetramine in :etone were effective in controlling rodents, protecting tree seed, and improving the stocking of eas seeded with Douglas-fir *(50, 73, 74, 142)* or ponderosa pine *(63, 151)*. The tetramine-acetone ɜatment, however, presented many difficulties. Even after modification *(152)*, it continued to duce germination *(50, 73, 96, 142, 151)* and cause seedling mortality *(142)*. Attempts to reduce ɜ loss in germination, which was thought to be caused mainly by the acetone *(151)*, led to coat- g seeds with an adhesive containing tetramine. Although the detrimental effect on germination rsisted *(44, 50, 130)*, satisfactory stocking of Douglas-fir *(44, 50, 96)* and ponderosa pine *(63, 0)* was obtained.

Tetramine has been suggested as a seedling treatment for decimating hares *(94)* and under rtain conditions may be superior to endrin in protecting seed *(44)*. Although some of the pro- rties of tetramine have been determined *(64, 164)*, we have no information on toxicity and effect metabolism, degree of storage, and excretion of the compound in big-game animals. The extreme cicity of tetramine to man and wildlife and the hazard that may be created by its use make deter- ıation of its effect and its behavior in animals a prerequisite to devising a safe control method treating seedlings in the field. The hazard question also emphasizes the necessity for addi- nal research in connection with evaluating proposals *(94)* for establishing toxic feeding stations ere a buried reservoir of the chemical would be available to the seedlings. Whether this tetra- ıe would be available to other vegetation (e.g., berries, salal, grass, etc.) and whether this uld constitute a hazard is still unknown. Determination of leachability, distribution, and sta- ity of tetramine in the soil and the relative absorption, translocation, and degradation of the ɜmical by different plant species would certainly be helpful in clarifying this point *(124)*. ıilar studies would be required in evaluating the proposal that a few trees treated with tetramine the nursery be included in new plantations *(94)*.

To establish a safe and effective nursery practice, the fate of tetramine in nursery soil must be ·ermined. Knowledge of the behavior of the chemical inside the plant is also necessary to explain reaction of animals to the treated seedlings in the field. Additional research should be aimed counteracting the undesirable effects of acetone or discovering a nontoxic solvent. In addition, valuation of the chemical must depend on a careful comparison with endrin, such as effect on ɜd embryos, ease of impregnating seed, and performance of treated seed and newly emerged ɜdlings in the field.

Endrin.—In spite of the relatively successful use of tetramine, the chemical never became nercially available *(149)*, and it was necessary to find another protective agent to replace it ɜed treatments. For this purpose, the U.S. Fish and Wildlife Service *(163)* recommended endrin,[6] nphytotoxic, commercially available insecticide. This was used in a seed-coating formulation aining an adhesive, the fungicide "thiram"[7] and aluminum powder *(149)*.

The formulation was somewhat effective in protecting coniferous seed from destruction by ɜ rodents *(42, 44, 75, 96, 133)* but was ineffective against ground squirrel populations *(148)*. ɜo inhibited seed germination *(44)* and, while this may have been due to thiram *(96, 143, 149)*, ɜdhesive or endrin itself may have contributed to the adverse effect.

Tetramine and endrin coating treatments were also used in attempts to protect natural seed rodent destruction by first exposing the rodents to artificially sown, treated seed of the same ies. This method, however, proved ineffective because the rodents apparently avoided the ·ed seed *(43, 96)*.

Endrin has also been used in attempts to protect seedlings from damage, Burns *(28)* sprayed ifferent toxic formulations on loblolly pine *(Pinus taeda* L. *)* seedlings and found that endrin the most effective. Meadow mice were controlled in Germany by spraying grasses and other tation with 0.01-percent endrin emulsion *(92)*, and satisfactory *Microtus* control was obtained ngland *(71)*.

Since its introduction in 1956, the endrin formulation has not been materially changed, and ɜts of its components on seed and seedlings are not known. Until a repellent compound or a effective toxicant with lower toxicity to humans and beneficial wildlife is discovered, the n treatment requires more investigation, particularly in connection with effects of its comnts on seed viability and survival of seedlings from treated seed. Development of an impreg-g technique *(93)* is also needed—provided endrin proves nontoxic to seed embryos *(124)*. Such ɜhnique would increase effectiveness of the treatment and may prove useful in cases where ɜoating treatment usually fails.

Strychnine.—Many toxic chemicals have been applied to seedlings and even to the ground tation to reduce hare and mouse damage to small trees. Use of such chemicals, however, will ɣs be a calculated risk with respect to the safety of beneficial wildlife and domestic livestock.

Strychnine was one of the first toxicants so used. The U.S. Forest Service and other agencies planting stock sprayed with adhesives containing strychnine, but reports on effectiveness of pray were conflicting and inconclusive *(91, 169)*.

Toxaphene.—Good control of meadow mice was obtained in Germany by spraying grasses and surface vegetation with 0.05-percent toxaphene emulsions.[8] Painting individual plant stems toxaphene gave protection against both mice and rabbits and was not harmful to deer *(107)*. factory protection of young seedlings and high levels of mouse *(Microtus)* control were also ned in preliminary experiments in England *(71)*.

1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo, endo-5,8-dimethanonapthalene. See Appen- further information.

Tetramethylthiuram disulfide.

Chlorinated camphene (67 to 69 percent chlorine).

Duration of protection.—Strychnine, endrin, and toxaphene are believed to be contact toxicants. Apparently they are not absorbed and translocated by the plant and thus do not provide protection to new shoots produced after the seedling has been treated. Protection is confined to the treated parts and probably lasts as long as the toxicant is present in sufficient concentration.

Long-term protection, on the other hand, might be obtained with systemic toxicants capable of being translocated into the new growth either from root or foliage applications. Kverno *(94)* found that a single soil treatment with tetramine produced toxic foliage for 4 years. He hypothesized that toxic plant feeding stations within deer-proof enclosures could be used for reductional control of hares. He also suggested treating a small proportion of the seedlings in a plantation, sufficient for controlling hares but at levels low enough not to endanger deer. The practical value of these ideas has not been demonstrated although work is now underway to evaluate them *(95)*. The future of any tetramine treatment as well as other systemic toxicants will depend largely on success in developing safer and more economical methods of use.

Manipulation and Exclusion of Mammals

Cultural

Improved seeding, planting, and stand-improvement techniques.—There is always a place for intelligent application of cultural practices as a means of alleviating mammal damage. Good ground preparation, covering the seed with mineral soil, and sowing during periods of low rodent population would reduce seed loss to rodents *(146)*. Injury by rabbits and hares could be minimized where feasible by using large seedlings of less palatable but fast-growing species *(9, 165)*. Clean cultivation and use of resistant seedlings would tend to lessen meadow mouse damage *(29, 81)*. Tree pruning might be helpful in reducing bear damage *(57)* and, when used in combination with thinning, could inhibit wood rat housebuilding activities *(76)*.

Supplementary feeding.—Lack of food, a main cause of excessive browsing and clipping, would be relieved by improving existing range conditions and by creating additional foods. Adams *(6)* and Roy *(131)* assumed that maintaining broad-leaved browse species would protect conifers from deer browsing. Rations of felled aspen *(Populus* spp.*)* were suggested to reduce hare damage *(9)*, and felled spruce provided considerable protection against deer *(80)*. The deliberate planning of deer range as a part of forest management, however, would provide much better protection *(101)*. Bleichert *(22, 23)*, therefore, proposed that from 1 to 3 percent of the forest in small and scattered patches be maintained as pastureland for deer. Planting of such areas to different foodstuffs would promote deer movement and thus reduce time available to debark or browse the trees *(140)*.

Weed and brush control.—Brush and weeds can be serious competitors to trees for moisture and nutrients. Moreover, they furnish ideal habitat for some rodents. High populations of meadow mouse are found only on areas supporting a moderate to heavy herbaceous cover *(29, 103)*. Hares, on the other hand, prefer brushy cutover lands *(111)*. Several workers have suggested eliminating or reducing vegetation density, presumably through cultivation, to minimize hare *(9)* and mouse *(29, 103, 118)* damage. Chemical weed and brush control offers many advantages over conventional cultivation methods, but only one account of the use of herbicides has been reported. Experiments at Colorado State University *(33)* have shown that 85 to 95 percent of pocket gophers die off 1 year after ranges are sprayed with 2,4-D.[9] These experiments demonstrate possibilities of the method and should stimulate further research.

[9] 2,4-dichlorophenoxyacetic acid.

Plant growth regulation.—Although growth regulators are used extensively in modifying growth and development of agricultural and horticultural plants, very few have been used in forestry. However, it is possible to develop these and other chemicals to achieve the same ends on forest tree seeds and seedlings. Several possibilities for animal-damage control appear evident. If seed would germinate sooner and height growth increase faster, seed and seedling would have a better chance of escaping rodents. Stems would be thicker, lateral shoots stronger, and root systems heavier, thereby increasing seedling resistance to damage and decreasing mortality.

Mechanical

Animal-proof fences to protect trees have been used in American forestry only to a limited extent because of their high cost. In recent years, however, cost of deer-proof fences has been reduced. Grisez *(61)* suggested the use of standing trees for fence support, and Ow *(117)* described a fence of nylon netting which can be tied to trees by nylon ropes.

Screens were used to protect seed spots from rodents as early as 1911 *(120)*. Since that time, screens of different forms have proven beneficial *(52, 144, 109)*. The cheapest and most practical screens, however, are the K-screens (cylinders of hardware cloth with partially closed tops) *(85)* as modified by Roy and Schubert *(132)*. They are not affected by large rodents or weather conditions and need not be removed from seed spots.

In addition to fences and screens, other protective covers and devices have been used with variable success. These include: mulches *(66, 170)*, newspaper pieces *(65)*, beer cans *(82)*, and gelatin capsules *(79)* to protect seed in seed spots from rodents; paper bags *(104)* and plastic strips *(106)* to protect terminal and lateral buds from deer browsing; metal sleeves with projecting prongs to protect trees against deer rubbing *(126)*; and metal bands to prevent squirrels from climbing cone-bearing trees *(153)*.

Systemic and Contact Repellents

Repellent rather than toxic chemicals are less hazardous to man, domestic livestock, and big-game animals and other forms of beneficial wildlife. An ideal repellent should be nontoxic to mammals. It must also be chemically stable over reasonable periods of time; nonphytotoxic; capable of being translocated into the plant; nondetrimental to soil, mycorrhizal fungi, or form and rate of growth of plants; inexpensive; and safe for man to use. Unfortunately, none of the chemicals that have been tested for repellency qualify as ideal.

There is no truly systemic repellent for treating seed or seedlings at this time. Claims of "repellency" attributed to some systemic chemicals appear to stem from lack of a satisfactory definition of the term. Such definition must be achieved to clear up current misunderstanding of what constitutes repellent properties of a chemical. In the meantime, the search must be continued for a truly systemic repellent through screening and testing programs.

Very little success has been reported with chemicals applied to seed or to the soil covering seed spots to repel rodents. Iodoform, naphthalene, iodine, zinc chloride, borax, quinine, tannic acid, carbolic acid, etc. failed to protect coniferous seed from rodents *(170)*. Shirley *(144)* found that red lead and sulphonated linseed oil applied to seed or to the soil after sowing gave only

light protection. More recently, Schubert *(139)* reported that red lead, zinc phosphide, and compound 1080 proved ineffective against rodents when applied to sugar pine seed. The need for an effective repellent for seed treatment, therefore, still exists.

Attention has also been given to protecting seedlings and trees from animals through use of contact repellents. Early attempts, confined largely to orchard trees, were not particularly successful *(68)*. It remained for the U. S. Fish and Wildlife Service, in cooperation with other Government agencies and chemical companies, to initiate testing of various chemicals in an attempt to discover and develop repellent chemicals suitable for both forest and orchard trees. Due to these efforts, several chemical compounds, in different formulations, were "discovered" and field tested. Repellent "96a" (suspension of copper carbonate, copper sulfate, and lime sulfur in ethylene dichloride, with asphalt emulsion and a synthetic resin as adhesives) was reported successful in preventing damage to trees by rabbits *(167)*. It soon became apparent, however, that organic compounds, especially those containing sulfur, nitrogen, the halogens, or combinations of these elements, were the most active repellents *(16)*.

ZAC and TMTD[10] were tested for 5 years against hares, meadow mice, and deer. Ten-percent ZAC or TMTD reduced damage by hares to Douglas-fir, white and red pine, black and white spruce, ponderosa pine, some deciduous species *(18, 20, 21, 165)*, and loblolly pine *(27)*. Small-scale studies indicate effectiveness in protecting Douglas-fir seedlings and 6-year-old ponderosa and lodgepole pines against meadow mice *(19, 21)*. Evaluated as deer repellents, effectiveness of ZAC or TMTD varied widely with species of deer, kind and size of test plants, amount of deer pressure, and length of test period *(18)*. Browsing of treated ponderosa pine seedlings by mule deer was reduced by 73 percent in central Oregon, but Douglas-fir seedlings were not protected from black-tailed deer in western Washington *(21)*. Trials against deer with these repellents should be evaluated directly on each site where a deer problem exists.

TMTD and ZAC have similar repellent properties, particularly against hares. Spray formulations, however, afford protection to seedlings for a very short period of time and may cause some burning of the needles. When planting stock in the nursery is sprayed, a certain amount of the spray reaches the soil, and the possibility exists that some ingredient in the formulation may inhibit beneficial microorganisms in the soil unless it is degraded or inactivated by some soil factor. Effects of the ingredients and their stability in nursery soils deserve investigation. It is equally important to determine stability of these compounds on plant surfaces and effects on the life processes of the plant.

A large number of commercial repellents have also been tested in other countries with some success. Examples of these repellents and the countries in which they were developed are: "Wiltex" *(12)*, Sweden; "Waldine I" and "Waldine II" *(128)*, Switzerland; "Spangol V" *(157)*, Denmark; "Regensburger Verbiss-und Schalschutzmittel–RVS" *(122)* and "Picetol F" *(123)*, Germany; and "Herbasan" and "Sinoxyd F" *(70)*, England.

The relative effectiveness of these foreign formulations, compared with the American repellents, is not known. However, all available repellents, American and foreign, are of the contact type which protect only the treated portion of the plant, not new growth. Annual applications are necessary for satisfactory protection until seedlings outgrow the reach of destructive animals. This method of application is obviously inadequate in view of the expense of repeated field application.

[10] See Appendix for formulation and other information.

Actidione[11] was found most effective against Norway rats in food acceptance and barrier ts *(168)*. A 1-percent formulation with 10-percent lacquer and 1-percent accelerator was ex-nely phytotoxic to Douglas-fir *(17)*. Similar formulations were injurious to hardwoods except en treatment was limited to stem application *(70)*.

A 5-percent formulation of TNB-A in an organic solvent mixed with resins provided excellent tection to hardwood tree species against hares *(18)*. Douglas-fir was also protected, but the mical proved to be somewhat phytotoxic *(17)*. It was harmful to needles of ponderosa and gepole pine but basal treatments were nonphytotoxic and fairly effective in reducing damage to ear-old seedlings by meadow mice *(18, 19)*.

Bone tar oil, applied directly to Douglas-fir seedlings or as a spray broadcast over planted as, failed to reduce deer damage *(99)*. This was as a 1-percent formulation with 10-percent plex AC-33 as adhesive and Tween-20 as a stabilizer.

Nicotine sprays gave satisfactory protection to deciduous trees against rabbits *(68)*. Clipping Douglas-fir by hares was reduced by application of 4-percent nicotine sulfate in an asphalt ulsion, with Triton X151 and Triton X171 as stabilizer and spreader.

A 10-percent aqueous emulsion of TN 2531 with 10-percent rhoplex AC-33 adhesive reduced ping damage by hares on Douglas-fir, ponderosa pine, and some hardwood species *(17)*. This ellent must be applied within 12 hours of mixing and for this reason was replaced by TN 2500.

A 10-percent aqueous emulsion of TN 2500 with 15-percent rhoplex AC-33 adhesive increased uglas-fir mortality, delayed emergence of terminal buds of red and white pine, but was not urious to balsam fir, black spruce, or hardwood species. In all tests, it provided some pro-tion against hares *(20)*. A 5-percent spray produced no phytotoxic effects, reduced deer brow-g on ponderosa pine *(18)*, and gave satisfactory protection to Douglas-fir against hare clipping *5)*.

A 10-percent aqueous emulsion of TMTM (tetramethylthiuram monosulfide) with 10-percent ethelene polysulfide or 10-percent rhoplex AC-33 adhesives reduced rabbit damage to Doug-fir and some hardwood species *(17)*. Testing of this compound was discontinued, however, in or of formulations of zinc dimethyldithiocarbamate-cyclohexylamine complex and tetramethyl-iram disulfide.

Spraying conifer seedlings with 10-percent Z.I.P. solution reduced deer damage during winter . This chemical also gave good protection from rabbits to Douglas-fir and some deciduous s *(17)*.

ea Repellents

Enclosing tree plantations with rope or string impregnated with repellent chemicals has been d experimentally to protect trees from mammals. Eygenraam *(49)* used string impregnated with e tar and obtained protection against deer for about 2 months. More recently, rope treated with

[11] Additional information on actidione and several other chemicals mentioned in this section is given in the appendix.

an animal tar in a commercial product called "Wam" was reported to have given protection against deer for 6 months *(51)*. The approach, however, is not new and other investigators question its effectiveness in controlling mammal damage *(68)*.

CONCLUSION

Damage to forest trees, seedlings, and seeds by wild mammals is an increasingly serious and, as yet, unsolved problem. Certainly, the economic values involved make it most urgent that we mount an increased research attack.

It is apparent that measures required to achieve control of wild mammal damage to forest values must be of a much more intensive nature than heretofore contemplated. Costs involved in application of mechanical barriers to animals rule out this approach to the problem on the millions of acres of forest land under consideration. Some help can be expected from cultural measures, intensified trapping and shooting of the larger problem animals, and other direct-action methods, but such efforts are feasible only on relatively small areas.

A review of the literature indicates clearly that a promising approach for the eventual control of wild mammal depredations is the improvement of chemical toxicants and repellents. Contact repellents and toxicants are only a stopgap because they protect only current growth. More effective and longer lasting results will require developing and perfecting the use of truly systemic toxicants or repellents.

A number of organizations, both public and private, are now engaged in research to help solve this problem. Screening and testing of chemicals is being done at increasing rates.

Development of new chemicals must be encouraged, aided perhaps by research on vegetation rarely accepted by some mammals. These plants, even though most succulent and probably nutritious, may contain active chemical compounds that make them unattractive to animals. Whether these chemicals are stable and active outside the plant and whether they can be identified and synthesized for use on conifers needs to be explored *(124)*. We also need more information on animal preference for food as a prerequisite to development of control chemicals.

The problem of wild mammal damage to forest values is increasingly serious and complicated in its solution. It can be solved, however, by strengthening the total research effort.

LITERATURE REFERENCES

Anonymous.
1953. Bears hamper tree growing in California. Jour. Forestry 51: 928-929.

Anonymous.
1955. The increasing problem of deer damage. The Timberman 56 (11): 48-51.

Anonymous.
1961. Porcupines serious menace to ponderosa pine in Oregon. The Forest Log 31: 1.

Abbott, Herschel G.
1961. White pine seed consumption by small mammals. Jour. Forestry 59: 197-201, illus.

——— and Hart, Arthur C.
1960. Mice and voles prefer spruce seeds.* U.S. Forest Serv. Northeast. Forest Expt. Sta. Sta. Paper 153, 12 pp., illus.

Adams, Lowell.
1949. The effects of deer on conifer reproduction in northwestern Montana. Jour. Forestry 47: 909-913, illus.

———
1951. White-tailed deer browsing on ponderosa pine plantations.* U.S. Forest Serv. North. Rocky Mt. Forest & Range Expt. Sta. Res. Note 89, 5 pp.

———
1955. Pine squirrels reduce future crops of ponderosa pine cones. Jour. Forestry 53: 35.

Aldous, Clarence M., and Aldous, Shaler E.
1944. The snowshoe hare – a serious enemy of forest plantations. Jour. Forestry 42: 88-94, illus.

Aldous, Shaler E.
1941. Deer management suggestions for northern white cedar types. Jour. Wildlife Mangt. 5: 90-94, illus.

Allen, G. S., Barber, I. K., and Mahood, Ian.
1955. The 1951 aerial baiting and seeding project, Ash River Tract, MacMillan & Bloedel Ltd. Forestry Chron. 31: 45-59, illus.

Andreasson, T.
1956. Om skydd mot viltskador: en redogörelse för några försök med kemiska medel. (Protection against damage by wild mammals: a report on experiments with a chemical product. In Swedish.) Skogen 43(1): 10-11. (Abstract in Forestry Abs. 17: 2996. 1956.)

lress requests to the originating office.

(13) Baader, G.
1956. Die wildschäden in Rheinland-Pfalz und vorschläge für ihre verminderung. Allg. Forst-u. Jagdztg. 127: 190-212.

(14) Baker, F. S., Korstian, C. F., and Fetherolf, N. J.
1921. Snowshoe rabbits and conifers in the Wasatch mountains of Utah. Ecology 2:304-310, illus.

(15) Balch, R. E.
1942. A note on squirrel damage to conifers. Forestry Chron. 18:42.

(16) Bellack, E., DeWitt, J. B., and Treichler, R.
1953. Relationship between chemical structure and rat repellency. Natl. Res. Council, Chem.-Biol. Coordination Center, Review 5: 48-156.

(17) Besser, J.
1955. Field and enclosure studies with experimental repellents for the protection of trees and shrubs from damage by rabbits and deer (1954-55).* U.S. Fish & Wildlife Serv. Wildlife Res. Lab., Denver, Spec. Rpt., 13 pp.

(18) _____
1957. Effectiveness of repellent treatments for protection of trees from animal damage (1956-57).* U.S. Bur. Sport Fisheries & Wildlife, Wildlife Res. Lab., Denver, Spec. Rpt., 19 pp.

(19) _____ Leskosky, S. T., and Dutton, R. W.
1959. Repellents for protection of forest seedlings from damage by meadow mice *(Microtus)*.* U.S. Bur. Sport Fisheries & Wildlife, Wildlife Res. Lab., Denver, Prog. Rpt. 2, 6 pp.

(20) _____ and Welch, J. F.
1956. Studies with repellents for protection of hardwoods and conifers from damage by rabbits and hares 1955-56.* U.S. Fish & Wildlife Serv., Wildlife Res. Lab., Denver, Spec. Rpt., 15 pp.

(21) Besser, Jerome F., and Welch, Jack F.
1959. Chemical repellents for the control of mammal damage to plants. 24th No. Amer. Wildlife Conf. Trans. 1955: 166-173.

(22) Bleichert, H. von.
1957. Einschränkung forstlicher Wildschäden durch Anlage von Grünland-Asungsflächen. Aus dem Walde 1: 89-100.

(23) _____
1958. Einige Gesichtspunkte zur Anlage von Grünland-Asungsflächen als Forstschutzmassnahme. Forst-u. Holzwirt 13 (7): 121-123.

(24) Bramble, William C., and Sharp, Ward M.
1949. Rodents as a factor in direct seeding on spoil banks in central Pennsylvania. Jour. Forestry 47: 477-478.

) Brent, Homer J., and Bowhay, Ellis L.
1956. Big game research - Food habits phase.* Wash. State Game Dept. Proj. 37-R-7, Quart. Prog. Rpt., 7 pp.

) Brown, E. R.
1961. The black-tailed deer of western Washington. Wash. State Game Dept. Biol. Bul. 13, 124 pp., illus.

) Burns, Russell M.
1960. Repellents reduce rabbit damage.* U.S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 129: 3-4.

) _____
1961. Rabbit repellents in north Mississippi.* Tree Planters' Notes 45: 19-22.

) Cayford, J. H., and Haig, R. A.
1961. Mouse damage to forest plantations in southeastern Manitoba. Jour. Forestry 59: 124-125, illus.

) Champagne, E. Garth.
1953. Browsing deer discouraged by repellent.* U.S. Forest Serv. Cent. States Forest Expt. Sta. Sta. Notes 80, 2 pp.

) Childs, Thomas W., and Worthington, Norman P.
1955. Bear damage to young Douglas-fir.* U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 113, 3 pp., illus.

) Church, Thomas W., Jr.
1954. Mice cause severe damage to Virginia pine reproduction.* U.S. Forest Serv. Northeast. Forest Expt. Sta. Res. Note 35, 2 pp., illus.

) Colorado Agricultural Experiment Station.
1959. Control of pocket gophers by 2,4-D. 72d Rpt. (1958-59): 8.

) Cook, David B., and Robeson, Stacy B.
1945. Varying hare and forest succession. Ecology 26: 406-410, illus.

) Corson, C. W., and Cheyney, E. G.
1928. Injury by rabbits to coniferous reproduction. Jour. Forestry 26: 539-543.

) Cowan, Ian McTaggart.
1945. The ecological relationships of the food of the Columbian black-tailed deer, *Odocoileus hemionus columbianus* (Richardson), in the coast forest region of southern Vancouver Island, British Columbia. Ecol. Monog. 15: 109-139, illus.

) Curtis, James D.
1944. Appraisal of porcupine damage. Jour. Wildlife Mangt. 8: 88-91.

) _____ and Wilson, Alvin K.
1953. Porcupine feeding on ponderosa pine in central Idaho. Jour. Forestry 51: 339-341, illus.

(39) Day, M. W.
1942. Rabbits – a hazard to coniferous plantations. Mich. Agr. Expt. Sta. Quart. Bul. 24: 252-253.

(40) DeBoer, S. G.
1947. The deer damage to forest reproduction survey. Wis. Conserv. Bul. 12: 3-23.

(41) Dice, Lee R.
1945. Some winter foods ofthe cottontail in southern Michigan. Jour. Mammal. 26: 87-88.

(42) Dick, James, Finnis, J. M., Hunt, Lee O., and Kverno, Nelson B.
1958. Treatment of Douglas-fir seed to reduce loss to rodents. Jour. Forestry 56: 660-661, illus.

(43) _____ and Lawrence, W. H.
1957. Protective seeding with tetramine-coated Douglas-fir seed.* Weyerhaeuser Timber Co. Forestry Res. Notes, 10 pp.

(44) Dimock, Edward J., II
1957. A comparison of two rodent repellents in broadcast seeding Douglas-fir.* U. S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Paper 20, 17 pp., illus.

(45) Dingle, Richard Wm.
1956. Pocket gophers as a cause of mortality in eastern Washington pine plantations. Jour. Forestry 54: 832-835, illus.

(46) Dixon, Joseph S.
1934. A study of the life history and food habits of mule deer in California. Calif. Fish & Game 20: 1-146, illus.

(47) Dodge, Wendell E.
1959. An effective poison and repellent for porcupine control. Jour. Forestry 57: 350-352, illus.

(48) Douglas-fir Second-Growth Management Committee.
1947. Management of second-growth forests in the Douglas-fir region.* U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta., 151 pp., illus.

(49) Eygenraam, J. A.
1957. Bone tar oil as a repellent for game. Instituut voor Toegepast Biologisch Onderzoek in de Natuur (Kemperbergerweg 11, Arnhem, Netherlands), Mededeling 35: 811-816, illus. (In Dutch. Reprinted from Landbouwk. Tijdschr. 69(10): 811-816. English summary in Wildlife Rev. 92, pp. 24-25.)

(50) Finnis, J. M.
1955. The use of tetramine in the direct seeding of Douglas fir in coastal British Columbia. Brit. Columbia Forest Serv. Res. Notes 31, 22 pp., illus.

l) Food and Agriculture Organization of the United Nations.
1961. I. Protection of plantations against game. Forestry Equipment Notes, A.24.61, 2 pp., illus.

2) Fowells, H. A., and Schubert, G. H.
1951. Recent direct seeding trials in the pine region of California.* U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Forest Res. Note 78, 9 pp.

) Fritz, Emanuel.
1951. Bear and squirrel damage to young redwood. Jour. Forestry 49: 651-652.

) _____
1951. More on bear damage: pack rats. Jour. Forestry 49: 917.

) Gaffney, William S.
1941. The effects of winter elk browsing, South Fork of the Flathead River, Montana. Jour. Wildlife Mangt. 5: 427-453, illus.

) Garman, E. H., and Orr-Ewing, A. L.
1949. Direct-seeding experiments in the southern coastal region of British Columbia, 1923-1949. Brit. Columbia Forest Serv. Tech. Pub. T-31, 45 pp., illus.

) Glover, Fred A.
1955. Black bear damage to redwood reproduction. Jour. Wildlife Mangt. 19: 437-443, illus.

) Graham, Samuel A.
1954. Changes in northern Michigan forests from browsing by deer. 19th No. Amer. Wildlife Conf. Trans. 1954: 526-533.

) Great Britain Nature Conservancy.
1957. Roe deer attracted to fertilized seedlings. Rpt., 1956-57, p. 10.

) Grisez, Ted J.
1959. The Hickory Run deer exclosure.* U.S. Forest Serv. Northeast. Forest Expt. Sta. Forest Res. Note 87, 4 pp., illus.

) _____
1959. A low-cost deer fence. Jour. Forestry 57: 42-43.

) Hamilton, W. J., Jr.
1941. The food of small forest mammals in eastern United States. Jour. Mammal. 22: 250-263.

) Harmon, Wendell H.
1954. Ponderosa pine seeding in the Black Hills. Jour. Forestry 52: 830-831.

) Haskell, A. R., and Voss, E.
1957. The pharmacology of tetramine (Tetramethylenedisulphotetramine). Jour. Amer. Pharm. Assoc. 46: 239-243.

(65) Hattersley, Joseph G.
1953. A method of direct seeding in rodent infested areas of summer drought. Jour. Forestry 51: 579.

(66) Hayes, W. D.
1913. Influence of birds and rodents in reforestation.* U.S. Forest Serv. Rev. Forest Serv. Invest. 2: 86-92. (Office rpt.)

(67) Herman, Carlton M.
1953. A review of experiments in biological control of rabbits in Australia. Jour. Wildlife Mangt. 17: 482-486, illus.

(68) Hildreth, A. C., and Brown, G. B.
1955. Repellents to protect trees and shrubs from damage by rabbits. U.S. Dept. Agr. Tech. Bul. 1134, 31 pp., illus.

(69) Hoene, John V.
1946. North woods beaver trouble. Amer. Forests 52: 538-539, 560, illus.

(70) Holmes, G. D.
1955. Experiments with chemical repellents for protecting trees against rabbits. *In* Report on forest research for the year ending March, 1954. Gt. Brit. Forestry Comn. London. pp. 148-158, illus.

(71) _____ Brown, R. M., and Ure, R. M.
1959. Preliminary experiments on the use of toxaphene and endrin for the control of short-tailed voles in young forest areas. *In* Report on forest research for the year ended March, 1958. Gt. Brit. Forestry Comn. London. pp. 148-156.

(72) Hooven, Edward F.
1953. Some experiments in baiting forest lands for the control of small seed eating mammals. Oreg. State Bd. Forestry Res. Bul. 8, 70 pp., illus.

(73) _____
1955. A field test of tetramine treated Douglas fir seed. Oreg. State Bd. Forestry Res. Note 21, 17 pp., illus.

(74) _____
1956. Field test of tetramine treated Douglas fir seed. Oreg. State Bd. Forestry Res. Note 29, 11 pp., illus.

(75) _____
1957. Field test of endrin-treated Douglas fir seed. Oreg. Forest Lands Res. Center Res. Note 28, 8 pp., illus.

(76) _____
1959. Dusky-footed woodrat in young Douglas fir. Oreg. Forest Res. Center. Res. Note 41, 24 pp., illus.

7) Hough, A. F.
1949. Deer and rabbit browsing and available winter forage in Allegheny hardwood forests. Jour. Wildlife Mangt. 13: 135-141, illus.

8) Howard, Walter E.
1958. Field-rodent control research needs.* Univ. Calif. Field Sta. Admin., Davis, 11 pp. (Office rpt.)

9) Huberman, M. A.
1940. Experimental direct seeding by the Forest Service.* U.S. Forest Serv. Div. Forest Mangt. Res., 57 pp. (Office rpt.)

0) Jascht, E.
1954. Der schälfangbaum. Allg. Forstztg. 65: 245.

1) Jokela, J. J., and Lorenz, Ralph W.
1959. Mouse injury to forest planting in the prairie region of Illinois. Jour. Forestry 57: 21-25.

2) Juhren, Gustaf.
1950. Protecting direct seedings in rodent-infested areas. Jour. Forestry 48 (9): 443-444.

3) Kangur, Rudolph.
1954. Shrews as tree seed eaters in the Douglas fir region. Oreg. State Bd. Forestry Res. Note 17, 23 pp., illus.

4) Kendall, J. C.
1932. Agricultural research in New Hampshire. N. H. Agr. Expt. Sta. 1931 Ann. Rpt. of Director, 30 pp.

5) Keyes, Joseph, and Smith, Clarence F.
1943. Pine seed-spot protection with screens in California. Jour. Forestry 41: 259-264, illus.

6) King, James E.
1958. Development of a stand of coniferous reproduction and interplanted Douglas-fir. Northwest Sci. 32: 1-8, illus.

7) Kittredge, Joseph, Jr.
1929. Forest planting in the Lake States. U.S. Dept. Agr. Dept. Bul. 1497, 88 pp., illus.

8) Krauch, Hermann.
1945. Influence of rodents on natural regeneration of Douglasfir in the Southwest. Jour. Forestry 43: 585-589.

9) Krefting, Laurits W., and Arend, John L.
1960. Effect of deer browsing on a young jack pine plantation in northern lower Michigan.* U.S. Forest Serv. Lake States Forest Expt. Sta. Tech. Notes 586, 2 pp.

(90) _____ and Stoeckeler, Joseph H.
1953. Effect of simulated snowshoe hare and deer damage on planted conifers in the Lake States. Jour. Wildlife Mangt. 17: 487-494.

(91) Kummel, Julius F., Rindt, Charles A., and Munger, Thornton T.
1944. Forest planting in the Douglas-fir region.* U.S. Forest Serv., 154 pp., illus.

(92) Küthe, K.
1956. Erfahrungen bei der bekämpfung der erdmäus *(Microtus agrestis* L.*)* in Oberhessen 1955. Anz. f. Schädlingsk 29: 161-164.

(93) Kverno, Nelson B.
1954. Development of better seed protectants. Jour. Forestry 52: 826-827.

(94) _____
1960. The problems in the use of systemic rodenticides. Soc. Amer. Foresters Proc. 1959: 97-98.

(95) _____
1961. Private communication. On file at Pac. NW. Forest & Range Expt. Sta. Silvic. & Anim. Prob. Lab., Olympia, Wash.

(96) _____ and Hartwell, Harry D.
1957. Pacific Northwest 1955-56 and 1956-57 experimental seeding studies.* U.S. Fish & Wildlife Serv. Bur. Sport Fisheries & Wildlife Prog. Rpt., 50 pp.

(97) Lauckhart, J. Burton.
1956. The effect of logging old-growth timber on bear. Soc. Amer. Foresters Proc. 1955: 128-130.

(98) Lawrence, William H.
1957. Porcupine control: a problem analysis.* Weyerhaeuser Timber Co. Forestry Res. Notes, 43 pp.

(99) _____
1960. Evaluation of bone tar oil as a deer repellent for Douglas-fir seedlings.* Weyerhaeuser Timber Co. Forestry Res. Note 32, 5 pp.

00) _____ Kverno, Nelson B., and Hartwell, Harry D.
1961. Guide to wildlife feeding injuries on conifers in the Pacific Northwest. West. Forestry & Conserv. Assoc., 44 pp., illus.

01) Leopold, A. Starker.
1950. Deer in relation to plant successions. Jour. Forestry 48: 675-678.

02) Levin, Oscar R.
1954. The South Olympic Tree Farm. Jour. Forestry 52: 243-249, illus.

03) Littlefield, E. W., Schoomaker, W. J., and Cook, David B.
1946. Field mouse damage to coniferous plantations. Jour. Forestry 44: 745-749, illus.

104) Loschek, H.
1960. Endlich ein 100 prozentig wirksames Pflansenverbisshutzmittel. Allg. Forstztg. 71 (21/22): 246.

105) Lutz, H. J.
1951. Damage to trees by black bears in Alaska. Jour. Forestry 49: 522-523, illus.

106) McNeel, Wakelin, Jr. and Kennedy, John.
1959. Prevention of browsing by deer in a pine plantation. Jour. Wildlife Mangt. 23: 450-451, illus.

107) Meyl, A. H.
1956. Praktische erfahrungen bei der erdmausbekämpfung. Forst-u. Holzwirt. 11: 429.

108) Miles, W. R., Krefting, L.W., and Hansen, H.L.
1961. Pocket gopher damage in red and Scotch pine Christmas tree plantations in central Minnesota. Minn. Forestry Note 110, 2 pp.

109) Miller, Charles I.
1940. An economical seed spot protector. Jour. Forestry 38: 733-734, illus.

110) Mitchell, Glenn E.
1950. Wildlife-forest relationships in the Pacific Northwest region. Jour. Forestry 48: 26-30.

111) Moore, A. W.
1940. Wild animal damage to seed and seedlings on cut-over Douglas fir lands of Oregon and Washington. U.S. Dept. Agr. Tech. Bul. 706, 28 pp., illus.

112) _____
1950. Forest tree-seed-eaters and methods used to measure their populations in the Pacific Northwest Douglas fir region. Univ. Wash. Forest Club Quart. 23 (1): 1-7, illus.

113) Munger, Thornton T.
1943. Vital statistics for some Douglas-fir plantations. Jour. Forestry 41: 53-56.

114) Neils, George, Adams, Lowell, and Blair, Robert M.
1955. Management of white-tailed deer and ponderosa pine. 20th No. Amer. Wildl. Conf. Trans. 1955: 539-551, illus.

115) Nettleton, Harry I.
1957. Wood rats damage young Douglas-fir. Jour. Forestry 55: 845.

16) Orr-Ewing, A. L.
1950. Rodent control in direct seeding through use of poisons. Brit. Columbia Forest Serv. Res. Notes 17, 8 pp., illus.

17) Ow, L. von.
1961. Hilfsmittel aus Kunststoff in der Forstwirtschaft. Allg. Forstzeitschr. 16 (16): 264-266.

(118) Parker, Lansing A.
1941. Factors causing rodent damage to tree plantations in southeastern Minnesota. Jour. Wildlife Mangt. 5: 297-303.

(119) Pearce, John.
1947. Identifying injury by wildlife to trees and shrubs in northeastern forests.* U.S. Fish & Wildlife Serv. Res. Rpt. 13, 29 pp., illus.

(120) Pearson, G. A.
1913. Methods of combating seed destroying animals.* U.S. Forest Serv. Rev. Forest Serv. Invest. 2: 82-85. (Office rpt.)

(121) Pike, Galen W.
1934. Girdling of ponderosa pine by squirrels. Jour. Forestry 32: 98-99.

(122) Pirsch, G.
1956. Verhütung von wildschäden im walde durch RVS. Allg. Forstztg. 67: 237-238.

(123) Puzyr, H.
1955. Eine neue Methode des kulturschutzes gegen wildverbiss! Allg. Forstztg. 66: 293.

(124) Radwan, M. A.
1962. Prevention and control of wild mammal damage on forest lands in the Pacific Northwest—a problem analysis and program of laboratory research.* (Office rpt. on file U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta.)

(125) Ratcliffe, F. N., Myers, K., Fennessy, B. V., and Calaby, J. H.
1952. Myxomatosis in Australia; a step toward the biological control of the rabbit. Nature 170: 7-11.

(126) Reisch, J.
1961. Die "Distel" ein neues Fegeschutzmittel. Forst-u. Holzwirt. 16 (7): 164.

(127) Resner, O. L.
1953. Damage to conifers by bear. 33d Ann. Conf. West. Assoc. State Game & Fish Comm. Proc., pp. 109-111.

(128) Rieben, E.
1959. La protection des fôrets contre les dommages provoqués par le gibier. Fôret 13(1): 10-12. (The protection of forest against deer damage. In French.)

(129) Riter, William E.
1952. The economic benefits derived from predator and rodent control.* U.S. Fish & Wildlife Serv., 7 pp. (Office rpt.)

(130) Roy, D. F.
1957. Seed spot tests with tetramine-treated seed in northern California. Jour. Forestry 55: 442-445, illus.

31) Roy, D. F.
1960. Deer browsing and Douglas-fir seedling growth in northwestern California. Jour. Forestry 58: 518-522, illus.

32) _____ and Schubert, G. H.
1953. K-screen seed spots.* U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Forest Res. Note 88, 2 pp.

33) Roy, Douglass F.
1961. Seed spotting with endrin-treated Douglas-fir seed in northwestern California.* U.S. Forest Serv. Pac. SW. Forest & Range Expt. Sta. Tech. Paper 61, 12 pp., illus.

34) Rudolf, Paul O.
1949. Porcupines' preferences in pine plantations. Jour. Forestry 47: 207-209, illus.

35) Scheffer, Theo. H.
1929. Mountain beavers in the Pacific Northwest: their habits, economic status, and control. U.S. Dept. Agr. Farmers' Bul. 1598, 18 pp., illus.

36) _____
1952. Spring incidence of damage to forest trees by certain mammals. Murrelet 33(3): 38-41.

37) Schindler, U.
1957. Erfahrungen der praxis bei der erdmausbekämpfung mit toxaphene und endrin. Forst-u. Holzwirt. 12(3): 33-38.

38) Schopmeyer, C. S.
1940. Successful forestation by direct seeding using poisons for rodent control.* U.S. Forest Serv. North. Rocky Mtn. Forest & Range Expt. Sta. Res. Note 1, 5 pp., illus.

39) Schubert, G. H.
1953. A trial of three chemicals as rodent repellents in direct seeding.* U.S. Forest Serv. Calif. Forest & Range Expt. Sta. Forest Res. Note 84, 2 pp.

40) Schulz, H. E.
1960. Rotwild und Forstschutz. Arch. f. Forstw. 9(1): 1-18. (English summary.)

41) Schwartz, John E. II, and Mitchell, Glen E.
1945. The Roosevelt elk on the Olympic Peninsula, Washington. Jour. Wildlife Mangt. 9: 295-319, illus.

42) Shaw, Elmer W.
1953. Effects of tetramine used for rodent control in direct seeding of Douglas-fir.* U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 89, 7 pp.

0

(143) Shea, Keith R.
1961. Field survival of thiram-treated Douglas-fir seed.* Weyerhaeuser Co. Forestry Res. Note 38, 8 pp.

(144) Shirley, Hardy L.
1937. Direct seeding in the Lake States. Jour. Forestry 35: 379-387.

(145) Siggins, Howard W.
1933. Distribution and rate of fall of conifer seeds. Jour. Agr. Res. 47: 119-128, illus.

(146) Smith, Clarence F., and Aldous, Shaler E.
1947. The influence of mammals and birds in retarding artificial and natural reseeding of coniferous forests in the United States. Jour. Forestry 45: 361-369.

(147) Spencer, D. A.
1950. The porcupine; its economic status and control. U.S. Fish & Wildlife Serv. Wildlife Leaflet 328, 7 pp.

(148) _____
1959. Prevention of mammal damage in forest management. Soc. Amer. Foresters Proc. 1958: 183-185.

(149) _____
1960. Research in rodent control in the United States with special reference to seed protection. 4th Internatl. Cong. Crop Protect. Proc. 4(2): 1357-1362.

(150) Spencer, Donald A.
1954. Rodents and direct seeding. Jour. Forestry 52: 824-826.

(151) _____ and Kverno, Nelson B.
1952. Research in rodent control to promote reforestation by direct seeding.* U.S. Fish & Wildlife Serv. Wildlife Res. Lab., Denver, Prog. Rpt. 3, 54 pp., illus.

(152) _____ and Kverno, Nelson B.
1953. Research in rodent control to promote reforestation by direct seeding; 1952-53 field experiments in reforestation and range improvement with tetramine treated seed.* U.S. Fish & Wildlife Serv. Wildlife Res. Lab., Denver, Prog. Rpt. 4, Sect. 1, 39 pp., illus.

(153) Squillace, A. E.
1953. Effect of squirrels on the supply of ponderosa pine seed.* U.S. Forest Serv. North. Rocky Mtn. Forest & Range Expt. Sta. Res. Note 131, 4 pp.

(154) Staebler, George R., Lauterbach, Paul, and Moore, A. W.
1954. Effect of animal damage on a young coniferous plantation in southwest Washington. Jour. Forestry 52: 730-733.

(155) Stillinger, C. R.
1944. Damage to conifers in northern Idaho by the Richardson red squirrel. Jour. Forestry 42: 143-145.

Stoeckeler, J. H., Strothmann, R. O., and Krefting, L. W.
1957. Effect of deer browsing on reproduction in the northern hardwood-hemlock type in northeastern Wisconsin. Jour. Wildlife Mangt. 21: 75-80, illus.

Strandgaard, H.
1958. Chemical protection of conifer plantations against browsing by game. Dansk Skovforen Tidsskr. 43: 559-578. (In Danish. Abstract in Forestry Abs. 20: 3371. 1959.)

Swift, E.
1948. Wisconsin's deer damage to forest reproduction survey—final report. Wis. Conserv. Dept. Pub. 347, 23 pp.

Switzenberg, D. F., Nelson, Thomas C., and Jenkins, B. C.
1955. Effect of deer browsing on quality of hardwood timber in northern Michigan. Forest Sci. 1: 61-67, illus.

Tevis, Lloyd, Jr.
1953. Effect of vertebrate animals on seed crop of sugar pine. Jour. Wildlife Mangt. 17: 128-131, illus.

_____
1956. Behavior of a population of forest-mice when subjected to poison. Jour. Mammal. 37: 358-370, illus.

Tinsley, Selden L.
1939. Direct seeding—a revival. Jour. Forestry 37: 888-890.

U. S. Fish and Wildlife Service.
1956. 1956 Formulation for the treatment of coniferous tree seed.* Wildlife Res. Lab., Denver, 2 pp. (Spec. Release.)

Voss, Elbert, Haskell, A.R., and Gartenberg, L.
1961. Reduction of tetramine toxicity by sedatives and anti-convulsants. Jour. Pharm. Sci. 50: 858-860.

Walters, J., and Soos, J.
1961. The relative efficiency of three hare repellants in protecting Douglas-fir seedlings. Forestry Chron. 37: 22-28, illus.

_____ and Soos. J.
1961. Douglas squirrel damage to Douglas fir, Univ. of British Columbia. Univ. Brit. Columbia Faculty of Forestry Res. Notes 32, 2 pp., illus.

Welch, J. F.
1948. Use of repellent 96a to protect trees and shrubs from rabbits.* (U.S.) Fish & Wildlife Serv., Wildlife Res. Lab., Denver. (Unnumb. Rpt., 2 pp.)

_____
1954. A review of chemical repellents for rodents. Jour. Agr. Food Chem. 2: 142-149.

(169) Wiksten, Ake.
1953. Strychnine spraying of planting stock. Weyerhaeuser Timber Co. Forestry Res. Notes, 7 pp., illus.

(170) Willis, C.P.
1914. The control of rodents in field seeding. Soc. Amer. Foresters Proc. 9: 365-379.

(171) Wodsak, W., and Ueckermann, E.
1955. Die Vitamingehalte der wichtigsten Baumrinden und deren möglicher Einfluss auf das Schälen des Rotwilds. (Vitamin contents of the bark of the principal forest trees, and their possible influence on bark-scaling by red deer.) Internatl. Ztschr. für Vitaminforsch. 25(4): 379-384.

(172) Zeedyk, William D.
1957. Why do bears girdle balsam fir in Maine? Jour. Forestry 55: 731-732.

APPENDIX

Supplementary Information on Some Repellent Chemicals

C. Panogen, Inc., Ringwood, Ill.

("Improved Z.I.P."). Zinc dimethyldithiocarbamate-cyclohexylamine complex with rhoplex AC-33.

TD--source Arasan 42-S or Arasan SF-X. E. I. DuPont De Nemours & Co., Inc., Wilmington, Del.

Tetramethylthiuram disulfide. Formulation with rhoplex AC-33 adhesive and suitable defoaming, thickening, and dispensing agents obtainable from Selco Supply Co., Eaton, Colo. ("Selco TMTD-Rhoplex Rabbit & Deer Repellent Concentrate "); formulation containing Arasan 42-S and a modified acrylic resin is available from O. E. Linck Co., Inc., Clifton, N. J. ("TAT-GO"); a 20-percent formulation is also available from Pennsalt Chemicals Corp., Tacoma, Wash. ("Penco Thiram Animal Repellent").

TIDIONE. The Upjohn Co., Kalamazoo, Mich.

B-(2-(3,5-dimethyl-2-oxocyclohexyl)-2-hydroxyethyl) glutarimide. Antibiotic.

B-A. Panogen, Inc., Ringwood, Ill.

("Ringwood Repellent"). Trinitrobenzene-aniline complex.

2531 (proprietary). Panogen, Inc., Ringwood, Ill.

2500 (proprietary). Panogen, Inc., Ringwood, Ill.

.P. B. F. Goodrich Chemical Co., Cleveland, Ohio.

("Good-Rite Z.I.P."). Zinc dimethyldithiocarbamate-cyclohexylamine complex with polyethelene polysulfide. Weathering properties are inferior to those of ZAC.

Some Animals Causing Damage to Forest Resources

Order	Suborder	Genera[1]	Common name
Artiodactyla	Ruminantia	*Cervus*	wapiti (elk)
		Dama	deer
Carnivora		*Ursus*	black and brown bear
Insectivora		*Blarina*	short-tailed shrew
		Scapanus	western mole
		Sorex	long-tailed shrew
Lagomorpha		*Lepus*	hare
		Sylvilagus	cottontail and brush rabbits
Rodentia	Hystricomorpha	*Erethizon*	porcupine
	Myomorpha	*Clethrionomys*	red-backed mouse
		Microtus	meadow vole
		Mus	house mouse
		Napaeozapus	jumping mouse
		Neotoma	wood rat
		Peromyscus	white-footed mouse
	Sciuromorpha	*Ammospermophilus*	antelope squirrel
		Aplodontia	mountain beaver
		Castor	beaver
		Eutamias	western chipmunk
		Perognathus	pocket mouse
		Sciurus	tree squirrel
		Tamias	eastern chipmunk
		Tamiasciurus	red squirrel
		Thomomys	pocket gopher

[1] After Hall, E. Raymond, and Kelson, Keith R. The mammals of North America. 2 v. New York: The Ronald Press Co. 1959.

Summary of Reported Wild Mammal Damage

	Literature reference
d destruction	
Motivation:	
Feeding	9, 62, 111
Animal causing damage:	
Antelope squirrel	145, 146, 162
Chipmunk	111, 145, 146, 160
Shrew	62, 83, 111, 112
Red-backed mouse	4, 5, 62
House mouse	146
Jumping mouse	62, 146
Meadow mouse	4, 88, 146
Pocket mouse	146
White-footed mouse	4, 5, 24, 62, 88, 111, 112, 146, 160
Effects of damage:	
Prevents or retards regeneration	24, 111, 129, 146, 162
May limit regeneration to species of low value	5, 88
ne severing	
Motivation:	
Feeding	111
Animal causing damage:	
Red squirrel	8, 153, 160
Effect of damage:	
Reduces current and, possibly, future seed crop	8, 153
owsing	
Motivation:	
Feeding	10, 26, 36, 46, 141
Animal causing damage:	
Deer	6, 10, 26, 40, 110, 114, 119, 131, 158
Elk	55, 119, 141
Effect of damage:	
Reduces stocking	7, 26, 89
Deforms trees	89, 156, 159
Reduces height growth	60, 89, 90, 131, 156
Reduces seedling competitive ability	6
Retards canopy closure	13
May increase proportion of low-value tree species	6, 58, 114

Clipping
Motivation:
Feeding (foliar damage) 9, 68, 81, 91, 98, 111, 165, 166
Burrowing (root damage) 91
Animal causing damage:
Hares and rabbits generally 9, 14, 41, 68, 77, 91, 111, 154, 165
Snowshoe hare 87, 111, 165
Rabbit *(Sylvilagus)* 48, 84
Rabbit *(Oryctolagus)* 100
Mountain beaver 86, 113, 136
Meadow mouse 100
Red squirrel 8, 15, 166
Wood rat 76
Porcupine 98
Pocket gopher 45, 108
Mole 91
Effect of damage:
Produces effects similar to those of browsing 9, 14, 26, 34, 35, 86, 165

Bud nipping
Motivation:
Feeding 119, 166
Animal causing damage:
Rabbit 68
Red squirrel 119, 166
Effect of damage:
Reduced growth 119, 166

Pulling, trampling, and rubbing
Motivation:
Feeding (pulling) 110
Antler polishing (rubbing) 119
Animal causing damage:
Deer and elk (pulling) 110
(trampling) 26, 110
(rubbing) 91, 113
Effect of damage:
Reduced stocking 26, 91

Tree cutting
Motivation:
Feeding 100, 119
Animal causing damage:
Beaver 100, 110
Effect of damage:
Loss of trees 100, 119
Flooding 69, 110

k stripping
Motivation:
Feeding--
deer and elk 119, 140
mountain beaver 113
red squirrel 119
bear 25, 53, 105, 1, 127, 172
Medication--bear 53
Nesting material--wood rat 115
Other--bear 105
Animal causing damage:
Bear 31, 53, 57, 97, 102, 105, 172
Deer and elk 119
Mountain beaver 100, 113
Red squirrel 119, 121, 155
Wood rat 54, 76, 115
Effect of damage:
Death of mature trees 31, 102
Top kill and deformation 121
Attack by other animals encouraged 57
Entry of decay organisms permitted 172
Storm resistance decreased 13

: gnawing
Motivation:
Feeding 9, 32, 68, 81, 91, 98, 111, 166
Animal causing damage:
Mountain beaver 136
Mouse *(Microtus)* 29, 32, 81, 100, 103
Pocket gopher 111
Porcupine 37, 38, 98, 134, 147, 3
Rabbit 68, 119
Red squirrel 119
Effect of damage:
Injury of trunk and branch 91, 113
Top kill and deformation 98
Death of both young and mature trees 68, 81, 98
Entry of decay organisms permitted 98
Reduction of seedling growth rate 81