SEED LOSSES
to Small Mammals after Fall Sowing of Pine Seed

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TO PROTECT PINE SEEDS

WHEN endrin and arasan came into use about 10 years ago as protective seed coatings, foresters believed they had an answer to the main problem in direct-seeding pine—how to keep rodents and birds from eating the seed. Though early trials were encouraging, recent reports have indicated that the chemical coating does not always give the seeds adequate protection (*Graber 1965, Langdon and Legrande 1965, Radvanyi 1966*).

So we made a study under field conditions to determine whether the degree of protection could be improved by increasing the endrin concentration in the seed coating. We found that, when the seeds were sown on the soil surface, seed losses due to small mammals were still severe—regardless of endrin concentration. The best results were obtained by covering the coated seeds with soil at planting time.

THE STUDY

This study was designed as a split-split-plot experiment. Three replications were established in burned-over scrub hardwood stands in southwestern Maine (table 1). Each main plot consisted of 6 furrows 12 feet apart and 132 feet long, plowed with a fireline plow. The 4 main plots in each replication were separated by at least 130 feet to minimize small mammal travel between plots. Each main plot was divided into two seed-ex-

Table 1.—Dominant vegetation and soils of the experimental areas

Replication	Dominant vegetation	Mean d.b.h.	Mean height	Stems per acre	Basal area per acre	Age	Origin	Soil series and type
		In.	*Ft.*	*No.*	*Sq. ft.*	*Years*		
Area I	Black oak, *Quercus velutina* Lam. White oak, *Q. alba* L.	2.5	20.0	889	30.84	18	Sprouting after fire	Windsor loamy sand
Area II	Black oak Gray birch, *Betula populifolia* Marsh Paper birch, *B. papyrifera* Marsh.	2.8	22.6	913	39.24	18	Seed and sprouting after fire	Charlton loam
Area III	Quaking aspen, *Populus tremuloides* Michx.	1.2	13.8	2,723	20.15	8	Sprouting after fire	Ninigret sandy loam

posure sub-plots, and each sub-plot was further subdivided into two sub-sub-plots to test differences between species. Treatments were assigned randomly at all levels.

We recognized that seed size and seed exposure might influence the effectiveness of the protective coating. So as part of our study, we used the small red pine (*Pinus resinosa* Ait.) seeds and the larger white pine (*P. strobus* L.) seeds to see if seed size influences depredation. We also compared two levels of seed exposure to see if seeds sown on the surface were more vulnerable to rodent depredation than seeds buried in the soil. The relatively large white pine seeds (28,000 per pound) were buried 1/3 inch deep and the smaller red pine seeds (53,400 per pound) were buried 1/4 inch deep. The surface exposure treatment consisted of simply dropping the seeds on the mineral soil seedbed.

The Protective Coating

We used Spencer's (*1959*) method to apply the protective seed coating. The endrin,[1] arasan,[2] and latex sticker were mixed together; then the seeds were tumbled in the mixture until they were coated.

Four endrin concentrations were used: 1/2 percent, the concentration recommended by Spencer; 1 percent, as suggested by Derr and Mann (*1959*) and later by Kverno (*1964*) where populations of seed predators were high; 2 percent, the concentration proved superior in our small-scale laboratory feeding trials with small mammals; and 4 percent, which is considered the practical maximum usable in a field experiment of this kind. The percentage of active endrin was based on the oven-dry weight of the seed to be treated.

The bird repellent, arasan, was applied at a rate of 1.5 percent effective ingredients per unit seed (oven-dry) weight. While the protective coating was still moist, the seeds were over-coated with aluminum powder.

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[1]Hexachloroepoxyoctahydro-endo-endo-dimethanonaphthalene. Source: Endrin 50W.

[2]Tetramethyl thiuram disulphide. Source: Arasan 75.

Seeding

Coated seeds of high viability (white pine 95.6 percent, red pine 98.0 percent) were planted in early November 1964. Seeds either were dropped on the surface or were buried in a small hole of appropriate depth. The seed spots were established in the center of the furrow at 3-foot intervals. Each sub-sub-plot contained 60 seed spots sown with 5 seeds. Thirty of these seed spots in each sub-sub-plot were randomly selected and were marked with wire pins for observations of seed loss.

Observations of Seed Losses

The marked seed spots were inspected closely at weekly intervals during snow-free periods in the fall and spring after seeding. Three observations were made in November before a lasting snowcover. Weekly observations were resumed on 1 April and continued until June. Most of the remaining seeds had germinated by then.

The purpose of these observations was to determine the cause, amount, and time of seed losses. Seed losses were classified as: (1) *consumed by small mammals* when characteristic seed hull remnants remained; (2) *removed by small mammals* when seeds were missing from a seed spot where consumption by small mammals had just occurred; (3) *missing* when seeds could not be located and no evidence was found to link the loss with a specific predator; (4) *consumed by birds* when typical seed fragments remained; (5) *consumed by insects*; and (6) *miscellaneous*.

The frequent inspections of the marked seed spots, together with the high visibility of the aluminum-pigmented seedcoats, made possible a reliable record of seed losses.

Screened Plots

A series of screened plots was established at randomly chosen seed spots that had not been selected for observation in the main study. These plots were established only where the seed was sown on the surface. The individual seed spots were protected as follows: (1) *exclusion of all predators except insects* with a 1/4-inch mesh screen cone 6 inches in diameter at the base: (2) *exclusion of birds and larger mammals* by an identical cone raised 1 inch off the ground to allow entry of small mammals; and (3) a *control* with no screen, completely open to all predators. Seventy-two of these single seed spot plots were established in each replication.

Small Mammal Census

A census of small mammals was made at 4-week intervals during the autumn and spring to follow population trends and species composition as related to the endrin concentration treatments. Fifty permanent live-trapping stations were established at each of the three replications. The stations were located on a 25-foot grid; 10 stations were on each of the 4 main plots, and 10 more were on an adjacent control plot where no seeding or site preparation had been done.

A Sherman live-trap baited with a rolled oats-peanut butter mixture and sliced apple was placed at each station. During the 5-day census periods, the traps were visited early each morning. Captured animals were examined, marked by toe clipping, and released. The resulting capture-recapture data were used as an index of small mammal activity on the study area.

RESULTS & DISCUSSION

Small Mammals

The first small mammal census was begun 15 October before site preparation and seeding operations, and the final census was completed 13 June. The peak catch occurred in the November trapping, with 130 captures. The number of captures in the December-May period averaged 73 per census. In June many juveniles entered the population, and the number of captures increased to 101. A total of 193 small mammals were captured 584 times from October to June.

By far the most important species in the small mammal population were the white-footed mice and red-backed voles (table 2). Together they accounted for 87 percent of the original captures and 100 percent of all recaptures. Both species

Table 2.—Species and number of small mammals captured during the seven 5-day census periods

Species	Animals captured	
	No.	*Percent*
White-footed mouse, *Peromyscus leucopus*	106	54.9
Red-backed vole, *Clethrionomys gapperi*	62	32.1
Masked shrew, *Sorex cinereus*	13	6.7
Short-tailed shrew, *Blarina brevicauda*	5	2.6
Eastern chipmunk, *Tamias striatus*	5	2.6
Red squirrel, *Tamiasciurus hudsonicus*	1	.5
Woodland jumping mouse, *Napaeozapus insignis*	1	.5
Total	193	100.0

are voracious consumers of pine seeds and were undoubtedly responsible for most of the seed losses that occurred in this study. The species of shrews found here feed largely on insects and other invertebrates and consume only small amounts of plant materials, including seeds (*Jackson 1961*). Since most of the shrews died in the trap (88 percent), they were virtually eliminated from the study area by the periodic trapping.

Chipmunks and red squirrels were captured or observed on areas I and II. The frequency of their capture is not indicative of numbers present in areas I and II because they were trap-shy, and none was ever recaptured. Only infrequently could seed fragments typical of their feeding be found, and it is believed that they had a minor effect on seed losses. This may be related to the good crop of oak mast that was produced on the two areas in the fall of 1964 and provided an abundant supply of their preferred food.

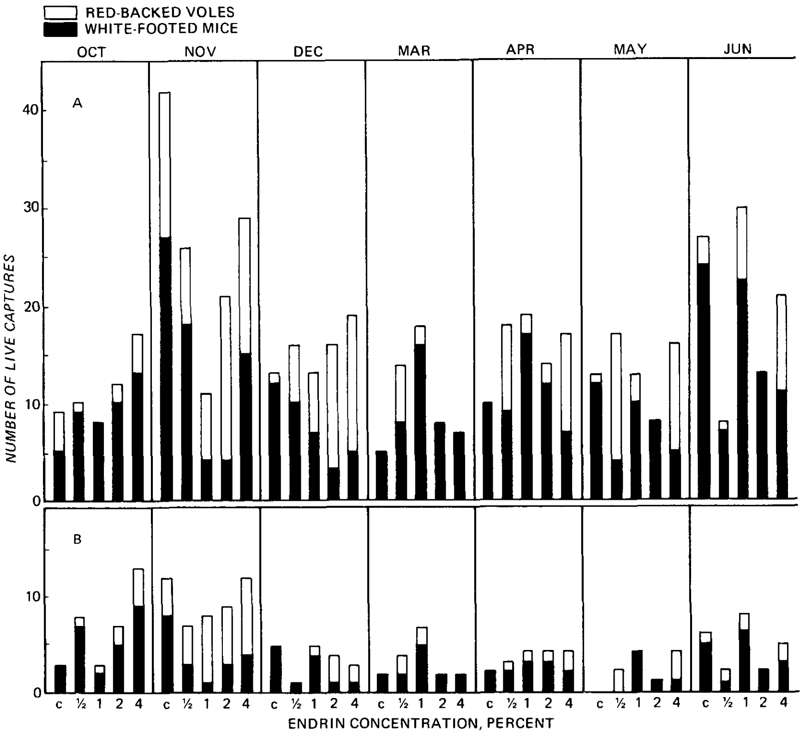
The small mammal populations were similar in number and species composition on the three replications except that there were no red squirrels or chipmunks on area III. The total number of small mammal captures and recaptures was 164 on area I, 201 on area II, and 219 on area III.

Effect of Endrin on Small Mammals

The four concentrations of endrin tested in the protective seed coatings appeared to have little effect on small mammal numbers or species composition.

A major possibility was that the small mammals living on or adjacent to the 2-percent and 4-percent endrin plots might suffer heavy mortality, and then the plots would be subject to reinvasion by animals from outlying areas. The animals most likely to show such a trend, if it did exist, were the white-footed mice and red-backed voles. The number of original captures and recaptures of these two species are shown in figure 1.

Figure 1.—Effect of endrin treatment on white-footed mouse and red-backed vole populations. The c (control) plots were not seeded. A, all captures, original plus recaptures. B, unmarked animals captured in each period.



No obvious decline in numbers or activity of the mice could be related to endrin concentration (fig. 1,A). A further measure of response to the protective seed coatings is the number of mice captured for the first time in each observation period (fig. 1,B). If the higher concentrations of endrin were causing mortality among mice, these plots would be invaded by animals from outlying areas, and the number of first-time captures on these plots would increase. This did not occur; heavy mortality due to endrin intoxication did not take place even at the highest endrin concentration. It appears that the effects of the higher levels of endrin in the protective coatings were minimal, lessening the possibility that the endrin concentrations tested here might cause significant injury to an existing small mammal population.

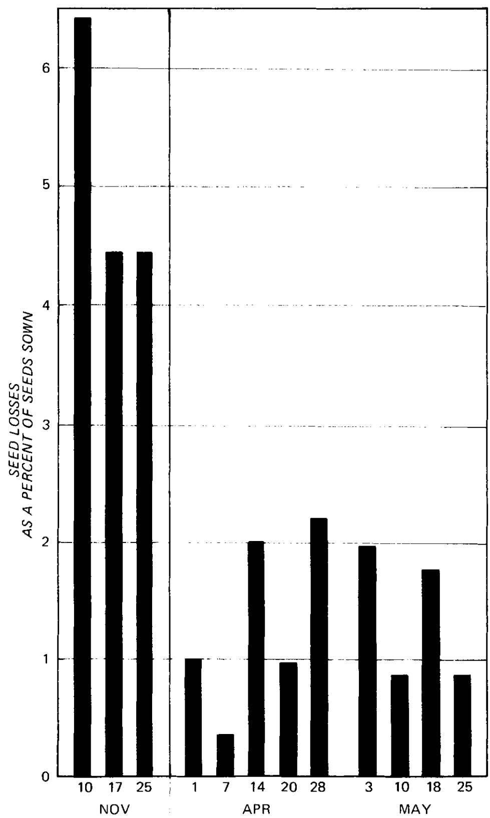


Figure 2.—Periodic seed losses from all causes during the dormant season (3 November to 25 May).

Time of Seed Losses

Heavy seed losses began immediately after sowing (fig. 2). At the end of the first week of exposure, 10 November, nearly 6 percent of the seeds on the observed seed spots had been destroyed. Fourteen percent of the seeds had been lost by the end of November, when a lasting snow cover made further observations impossible. In the spring the first weekly observation was made 1 April. Most of the losses observed at this time had occurred the previous fall between the time of the last observation, 25 November, and the first snowfall, which occurred 2 days later. This was apparent because of the weathered condition of the seed fragments. The level of seed losses increased erratically: peak spring losses occurred the last week of April and the first week of May. Total spring seed losses over the 9-week observation period were 12 percent. This indicates that maximum seed destruction may occur in the fall, and a lower level of seed destruction may occur over a much longer period in the spring.

Causes of Seed Loss

The major cause of seed loss was predation by small mammals (fig. 3). They consumed nearly one-half of all seeds lost. An additional one-third of all seeds lost were removed from seed spots where identifiable feeding had occurred. It was assumed that the animal responsible for the feeding had also removed the seed. Seed loss due to both consumption and removal by small mammals was 82 percent of the total seed loss.

Birds caused minor seed loss, approximately 1 percent of all losses. This most likely reflects the very small number of birds on the study area during late fall and early spring. Also, the arasan in the seed coating is a highly effective bird repellent.

No evidence of damage caused by insects was found. Loss due to miscellaneous factors, including trampling—by deer, hunters, a dairy cow, and occasionally the observers—was also minor. A final category was missing seeds, those that could not be located and where no concrete evidence could be discovered to link their disappearance with any other cause. However,

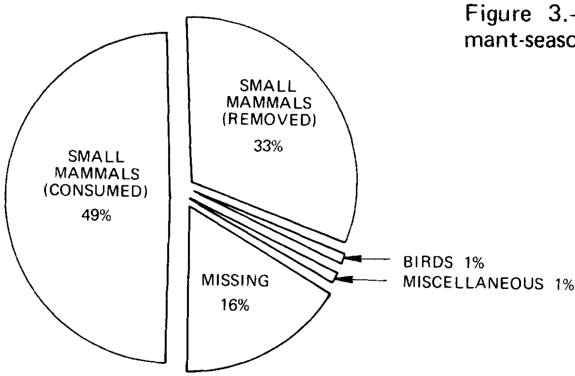


Figure 3.–Causes of dormant-season seed losses.

seeds in this category disappeared at a relatively constant rate, proportional to the seed loss caused by small mammals. It is probable that many of the missing seeds were in fact removed by these animals.

Seed Exposure

The experimental treatment having the greatest effect on seed loss was seed exposure. More than half of all seeds exposed on the surface were lost during the 7 months from 3 November to 25 May. Where the seeds were covered, less than 3 percent were lost.

At first it seemed strange that the small mammals did not discover and destroy more of the buried seed. Of the few covered seeds that were taken, almost every one had been lifted to the surface by frost action or soil washing. In very few places did it appear that an animal purposefully dug down to the seeds. Our hypothesis is that the covered seed, coated with protective chemicals, did not attract the attention of the seed-eating mammals. There can be no doubt that the animals present were capable of finding the seeds (*Howard and Cole 1967*). A possible explanation for their failure to do so is that the protective coating masked the odor of the seed or for some reason the odor was not associated with a known food source, even though coated seeds exposed on the surface nearby were being consumed.

Endrin Concentration

Because 95 percent of all seed losses occurred on the surface-sown plots, only they will be considered in this discussion. The effects of the endrin concentration treatment on seed losses were not statistically significant. This result appears to be due to the original study design, which provided a relatively insensitive test of the endrin concentration variable, and to the occurrence of a large within-treatment variation. However, an inspection of the data leads us to believe that real differences may exist (table 3). Certainly fewer seeds were lost at the 4-percent concentration than at the 1/2- or 1-percent concentration.

The influence of endrin concentration on the amount and time of seed loss is of particular interest (fig. 4). During the fall fewer than 10 percent of the surface-sown seeds coated with 4-percent endrin were destroyed while seed losses at the other concentrations ranged from 28 percent to 44 percent. In the spring the trend changed. Seed losses in the 4-percent endrin treatment exceeded all but those in the 1/2-percent treatment.

To some degree this increased proportion of seed loss in the most severe endrin treatment may simply reflect seed availability. Many more 4-percent endrin-coated seeds were exposed in the spring because much higher percentages of the seeds in the other endrin treatments had been destroyed in the fall. It is logical to assume that the small mammals responsible for over

Table 3.—Total number of seeds lost during the dormant season
(Seeds exposed on the surface)

Replication	Endrin concentration				
	1/2%	1%	2%	4%	Σ
I	68	190	107	58	423
II	209	122	147	63	541
III	273	265	186	162	886
Σ	550	577	440	283	1,850

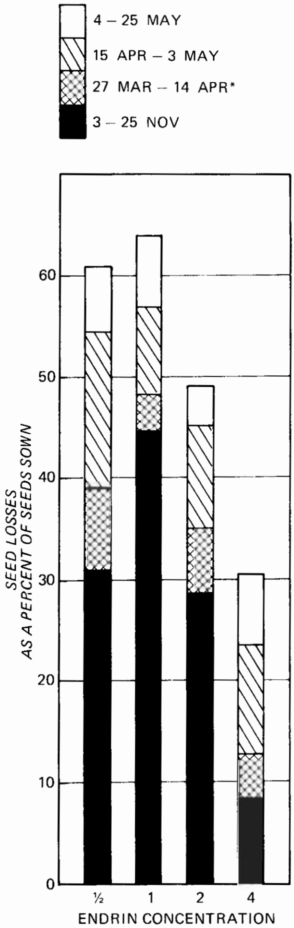


Figure 4.—The influence of endrin concentration on seed losses from 3 November to 25 May. (Seeds exposed on surface.)

*Seed losses occurring after 25 November and before a lasting snow cover 2 days later are included here.

82 percent of the seed loss consumed and removed the seeds treated with the lowest endrin concentrations first; and in the spring, when the low-endrin concentration seeds were relatively scarce, they destroyed larger amounts of the high-endrin seed.

Weathering of the protective coating would also tend to reduce differences among the endrin treatments. By spring the coating had visibly deteriorated; large flecks of the coating had sloughed off the seeds exposed on the soil surface.

A visual estimate of the loss of protective seed coating was made in late May. The average coating loss was approximately

Table 4.—Number of seeds lost to small mammals
(Seed exposed on the surface)

Endrin concentration (percent)	Consumed	Removed	Total	Consumed/removed ratio
1/2	242	253	495	0.94
1	237	230	467	1.03
2	220	136	356	1.62
4	129	61	190	2.11

40 percent; loss ranged from 0 to 100 percent. This loss of coating undoubtedly reduced the effectiveness of the endrin treatment and was a factor in the high spring losses of seeds coated with 4-percent endrin.

Endrin concentration had an effect on the proportion of seeds consumed to seeds removed (table 4). Where seeds were coated with 1/2-percent endrin, small mammals removed slightly more seeds than they consumed. At the highest endrin concentration, more than two seeds were consumed for each seed removed.

Consumption and then removal of some or all of the remaining seeds, presumably to a cache, reflects a higher degree of small mammal acceptance than consumption alone. That is, animals that consumed seeds treated with the higher endrin concentration may have been so repelled by the protective coating that relatively few seeds were removed for storage.

Effect on Species

White pine seed loss, although greater, was not significantly different from red pine seed loss. Where the seeds were exposed on the surface, 58 percent of the white pine seeds were lost and 45 percent of the red pine seeds were lost. These differences reflect mainly what appears to be selective feeding by small mammals in November when 32 percent of the white pine seeds were destroyed compared to 23 percent of the red pine seeds.

In the spring, seed losses were nearly identical for the two species.

Screened Seed Spots

The protection afforded by the conical screen covers had a major effect on seed losses. When the base of the cone was in firm contact with the soil, excluding all seed predators but insects, only 3.6 percent of the seeds were lost. In no case were any seed fragments found linking this loss with any predator, including insects; the seeds simply vanished. Most likely soil disturbance caused by frost heaving and rain washing was responsible for this seed disappearance. Most of these losses occurred during relatively cold portions of the dormant season when the soil was freezing nightly—a time when little insect activity would be expected.

Where the screen cones were raised 1 inch (open-cone), allowing the entry of small mammals, losses were surprisingly light; only 27.5 percent of the seeds were lost. The proportions of seed loss caused by each agency was almost identical to those in the main study (fig. 2), except that no seeds were taken by birds.

The unprotected seed spots suffered the heaviest loss (61 percent), exceeding by nearly 10 percent the loss that occurred on the main study under similar conditions. However, the proportion of seed loss caused by each agency was very similar to that in the main experiment. Small mammals were responsible for 85 percent of all losses on the unprotected seed spots and a similar proportion (82 percent) in the open-cone seed spots. The large difference in total seed losses between the open-cone and the unprotected seed spots may indicate that the small mammals were reluctant to enter the open cones. Another observation that supports this hypothesis is that nearly 60 percent of the seeds destroyed by small mammals were consumed on the unprotected seed spots, but only 44 percent of those destroyed on open-cone spots were consumed there. The rest were removed, presumably to the protective cover of the adjacent familiar habitat.

CONCLUSION

Heavy seed losses caused by small mammals, primarily white-footed mice and red-backed voles, occurred wherever seeds treated with the recommended concentrations of endrin (1/2 and 1 percent) were exposed on a mineral seedbed. An increase in the endrin concentration of the seed coating appeared to reduce losses, but the reduction was not statistically significant.

Birds caused only minor seed losses. Because birds are the major seed predators in the South, this result may be surprising. However, the migratory birds were gone before sowing in the fall and did not return until just before germination in the spring. And, arasan, which was a component of the protective seed coating, is an effective bird repellent.

The time of seed loss is particularly interesting. More than half of all seed losses occurred during the 3 weeks in the fall after sowing and before a lasting snow cover. This result is no doubt related closely to the large number of small mammals present at this time. A logical conclusion is that fall sowing should be avoided, especially when small mammals are abundant and the seeds are to be left exposed on the seedbed surface.

When given a clear choice, the seed predators might select the larger white pine seeds in preference to red pine seeds. But the differences between the two species were not significant statistically and are not likely to be of practical importance because both species were readily accepted by the predators. For both species, the amount of seeds destroyed was great where seeds were sown on the surface and exceeded a level that could be readily tolerated in practical regeneration operations.

The most important observation of this study was that very few seeds were lost when the seeds were covered with soil; and more than half of the seeds sown on the surface were destroyed—primarily by small mammals. This means that methods of direct seeding that cover the seeds are much more efficient than broadcast methods. This is especially so where seed is scarce or expensive. In the past, seeds that had to be covered with soil were sown by hand because the rough, stony, wooded land so typical of New England prevented the use of machinery. And hand sowing was almost prohibitively expensive. But a recently developed mechanized seeder (*Graber and Thompson 1967*) sows and covers the seeds efficiently, providing a practical application of this finding.

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