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DESTRUCTION OF CONIFER SEED AND METHODS OF PROTECTION

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ABSTRACT: Agents responsible for losses of conifer seed and methods for seed protection are reviewed. Published information indicates that much seed is destroyed, especially by seed-eating rodents and birds. Improvement of existing protective methods and development of new chemical means are necessary to overcome the problem.

INTRODUCTION

Unlike many deciduous tree species which are easily propagated vegetatively, most conifers are reproduced naturally and artificially from seed. Success of conifer forest regeneration, therefore, depends on production of sufficient quantities of high quality seed. This can be achieved by foresters only by thorough knowledge of factors affecting seed production and protection of the seed crop from many natural destructive agents.

Presently, the trend in artificial reforestation is toward planting rather than direct-seeding. However, seeding will probably remain the more economical and perhaps the only suitable reforestation method in many situations and may even become more widespread if associated problems are better understood and effective methods to minimize failures are developed. The overall problem of seed destruction and methods of protection, therefore, are reviewed in this paper to guide present and future reforestation efforts with conifer seed.

SEED DESTRUCTION

From the time of its formation in the cone until germination following natural or artificial dissemination, conifer seed is subject to damage by various biotic agents. The destructive organisms include seed-eating rodents, birds, insects and other invertebrates, and fungi.

Numerous studies, conducted at several locations, indicate that seed-eating rodents can consume considerable quantities of the various species of conifer seed, and thus contribute importantly to reforestation failures (e.g., Moore 1940, Adams 1950, Abbott 1961, Stephenson et al. 1963, Boyer 1964, Gashwiler 1967). The white-footed mouse (*Peromyscus* spp.), is considered the main offender (Moore 1940, Smith and Aldous 1947), although ground squirrels (*Citellus* spp.) (Tinsely 1939), chipmunks (*Tamias* and *Eutamias* spp.) (Smith and Aldous 1947, Adams 1950), and shrews (*Blarina* and *Sorex* spp.) (Hamilton 1941, Kangur 1954) also eat large amounts of seed in some locations.

Birds, especially the southern meadowlark (*Sturnella magna*) and blackbirds (*Agelains* and *Euphagus* spp.), are important seed predators in the South (Burleigh 1938, Derr and Cossitt 1955). The junco (*Junco* sp.) and other bird species also destroy seed in other parts of the country--apparently more than is generally assumed (Krauch 1936, Hagar 1960, Gashwiler and Ward 1968).

As with other species, conifer seed is damaged by insects and disease organisms. Important insects include the carabid beetle (*Pterostichus* sp.) (Johnson et al. 1966) and various species of ants (Boyer 1964), while molds are probably the pathogens responsible for most seed losses due to disease (Lawrence and Rediske 1962).

Appraising seed destruction in the field is an exceedingly complex task. Damage caused by each agent varies by area, seed species, season, and year. In addition, methods to accurately assess factors responsible for seed losses have not been developed. Examination of mechanically protected or unprotected seed spots disturbs the seed and has often failed to account for a high percentage of the sown seed (Stein 1957). On the other hand, use of isotopes (Lawrence and Rediske 1962, Radvanyi 1966) has so far produced biased results mainly because the technique has been used with seed treated with protective chemicals.

Based upon available information, foresters and wildlife biologists generally agree that seed-eating rodents and birds (especially in the South) are the main pests which destroy conifer seed. So far, measures to protect seed, therefore, have been devised primarily to control damage by these two agents. As our knowledge expands and seed becomes more valuable, it may be possible to develop broader methods which would protect seed from most predators.

SEED-PROTECTION METHODS

Following are methods for protecting conifer seed from destructive organisms and appraisal of present use and future prospects of each method.

Mechanical Methods

Mechanical barriers have long been used to exclude animals and thus protect conifer seed in seed spots. Mulches (Willis 1914), newspapers (Hattersley 1953), and even beer cans (Juhren 1950) have also been used with varying success.

Wire screens, made from hardware cloth or window screening, provide the best mechanical protection (Miller 1940, Keyes and Smith 1943). Screens can be made in several different shapes and sizes (Keyes and Smith 1943, Stoeckeler and Scholz 1956); some are partially closed at the top and do not require removal after seed germination (Roy and Schubert 1953). Screens provide good protection from birds and small rodents, but not from larger rodents, insects, or fungi. They are also subject to damage by trampling, heavy snow and rain, and frost heaving.

At present, use of screens to protect seed is apparently limited to regeneration of small areas and establishing study plots. Greater use, however, could result from improving the screens and reducing the cost.

Poison Baiting

Poison baits, formulated from a poison, oats or wheat, and a coloring agent, have been used to control seed-eating rodents when applied shortly before natural seedfall or artificial seeding. Currently, most poison baits for rodents on forest lands contain sodium fluoroacetate (1080)[1/]. The chemical is applied to grain at 2 oz./100 lb. (0.1 percent) for hand distribution of 2 to 4 lb./acre and at 10 oz./100 lb. (0.5 percent) for aerial application of 1/2 lb./acre. Originally, the 10-oz. bait was recommended on the basis that one treated kernel is lethal to a mouse. This, however, does not fully explain the basis for the recommended concentrations and rates of application which do not appear to have been adequately tested. Recent tests, therefore, have been conducted by the University of California in Davis. Results indicate that reductions in amounts of 1080 applied are possible without impairing the effectiveness of the treatment (Unpublished data). Clearly, this work should be extended until minimum, effective concentrations of 1080 and amounts of bait material are established if use of this chemical is to be continued.

With 1080 bait, only very short periods of rodent control are possible since initial rodent populations are not completely eliminated and reinfestation from untreated areas is usually rapid. Effective control, therefore, can be achieved only by including buffer strips (Hooven 1953) or by rebaiting (Stein 1964).

Other disadvantages of 1080 baits are hazards of primary and secondary poisoning to nontarget species, lack of effective antidotes, and absence of warning symptoms following ingestion. Replacement of 1080, therefore, is desirable. Accordingly, researchers of the Department of Animal Physiology at the University of California in Davis have been experimenting with new chemicals, especially Diphacinone (2-Diphenylacetyl-1,3-indandione) at concentrations much lower than those used with 1080. These chemicals are slow-acting anticoagulants; and since vitamin K is an antidote, they are considered much safer than 1080. Recently, Neochem Products Company has obtained Federal registration for a 2.0-percent Diphacinone concentrate (Diphacin 110-A) which, at least for the present is available only in California. This concentrate is used to prepare a 0.01-percent Diphacinone bait which has been registered for deer mouse control in some counties in California. Gophacide (O,O,bis[p-chlorophenyl] acetimidoylphosphoramidothiolate) was also tested recently against deer mice in California, and results indicated good control (Hoffer et al. 1969); the chemical, however, is not commercially available now and it is doubtful that it will be in the near future. In addition to work with Diphacinone, therefore, other candidate toxicants should be tested to identify the best possible replacement for 1080.

1/ Mention of chemicals or chemical companies does not represent endorsement by the Forest Service or by the Department of Agriculture.

Evaluation of new chemicals for poison baits must always include assessment of fate of residues and hazards to operators and to nontarget wildlife. In addition, attempts should be made to develop meaningful guides for baiting. Such criteria would specify numbers of rodents before treatment is necessary and conditions which require baiting when conifer seed is already treated with protective chemicals.

Chemical Treatments Of Seed

Since the early days of direct-seeding, many attempts have been made to protect conifer seed from rodents by applying various chemicals to the seed. Examples of chemicals used with very little success are: iodoform, naphthalene, iodine, zinc chloride, borax, tannic acid (Willis 1914), red lead, sulfonated linseed oil (Shirley 1937), and zinc phosphide, and 1080 (Schubert 1953). In the 1950's, the U.S. Bureau of Sport Fisheries and Wildlife began a screening program to find a suitable chemical protectant for conifer seed. This program so far, has yielded two chemicals, tetramine (tetramethylenedisulphotetramine) and endrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-endo-endodimethanonaphthalene).

Tetramine was used only experimentally. Although it protected conifer seed (Hooven 1956, Dimock 1957), the chemical inhibited germination (Finnis 1955, Roy 1957) and did not protect seedlings resulting from treated seed as originally claimed (Roy 1957). In addition, tetramine never became commercially available, mainly because of its extreme toxicity and hazards associated with its production.

Endrin is the only chemical now being applied directly to conifer seed to protect it mainly from rodents. Since 1956, the U.S. Bureau of Sport Fisheries and Wildlife has recommended the chemical as a coating treatment at 0.5 percent, with Arasan (tetramethylthiuram disulphide, TMTD) as a fungicide and bird repellent, a coloring material (aluminum powder or Monastral green pigment) to identify treated seed and discourage bird feeding, and an adhesive (Dow Latex 512 R or Rhoplex AC-33) to hold the chemicals on the seed (Anonymous 1956). Essentially, seed is treated either by (1) slurrying one or more of the ingredients in the adhesive and then applying the slurry to the seed, or (2) by wetting seed with the adhesive, adding the active ingredient(s), and then covering the wet seed with the coloring material. Treated seed is finally dried overnight and kept in containers until sown.

Initial evaluations of the endrin treatment indicated adequate protection for conifer seed, especially with Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) (Dimock 1957, Dick et al. 1958, Roy 1961) and the southern pines (Pinus spp.) (Derr and Mann 1959, Royal and Ferguson 1962). The treatment, however, inhibited germination (Dimock 1957, Dick et al. 1958) and did not protect seed on some areas, especially where chipmunks and ground squirrels were present. In the early sixties, therefore, the original endrin treatment was modified. In the West, Arasan was eliminated from the treatment; this bird repellent was not considered necessary since birds were not important and because the chemical inhibited germination, and in one field study did not significantly improve protection from rodents (Dick et al. 1958). In contrast, foresters in the South increased Arasan in the treatment, and replaced the solid chemical with the liquid form, Arasan 42-S (Mann 1968). Also, in most areas, endrin concentration was increased to 1.0 percent.

In Forest Service research in Olympia, we recently investigated endrin on Douglas-fir seed in the laboratory. To date our published results (Radwan et al. 1970, Radwan and Anderson 1970) and unpublished data indicate that: (1) 0.5-percent endrin (without Arasan) is a poor treatment against caged deer mice; doubling the endrin concentration significantly increases effectiveness of the treatment, mostly through an increase in animal mortality, (2) seed commercially treated with both 0.5 and 1.0 percent endrin sometimes contained much less endrin than expected, and significant amounts of this endrin may be lost in sowing with helicopter and by weathering after seeding, (3) Arasan (up to 8 percent from Arasan 42-S) does not protect seed from mice, (4) 0.5-percent endrin plus 8-percent Arasan (from Arasan 42-S) is an effective coating treatment against mice; the treatment reduces feeding on seed with minimum animal mortality, and it does not inhibit germination significantly, (5) without inhibiting germination, seed is readily impregnated with endrin using dichloroethane (ethylene dichloride) as solvent; impregnated seeds contain less endrin and are more effective against mice than is possible with the 0.5-percent endrin treatment, and (6) both coated and impregnated seeds can be stored without reduced germination for up to 4 months, regardless of storage temperature.

Clearly, application of recent research findings would greatly improve the endrin treatment. However, concern by the public over use of chlorinated hydrocarbons in pest control, and recent action by the U.S. Department of Agriculture limiting use of endrin on Forest Service land, indicate that the endrin treatment of conifer seed will be phased out despite lack of concrete evidence for claimed or suspected hazards from its use. Consequently, we believe that major research efforts by all concerned agencies should be directed to replacing endrin. Researchers have learned much from work with endrin, and this experience will undoubtedly prove helpful in developing a more acceptable seed treatment.

Chemicals have been applied to conifer seed to protect it from birds. Anthraquinone and Arasan provided the southern pines with adequate protection (Mann et al. 1956, Derr and Mann 1959). Colored materials (i.e., aluminum powder or green pigment) and Arasan have also been used on endrin-treated seed to repel birds. Unfortunately, claimed benefits from these chemicals in presence of endrin have never been adequately documented, and seed losses to birds and some bird kills still occur. Research on bird repellents, therefore, is needed in order to discover better chemicals which could be safely used on conifer seed with and without rodenticides.

Biological Methods

During the third Vertebrate Pest Conference, Howard (1967) presented an excellent review on biological control of vertebrate pests. The following will deal with such methods only as they apply to protection of conifer seed from forest animals:

Predators.--Owls, hawks, and some carnivorous mammals are among the natural predators of seed-eating rodents, but it is doubtful that rodent populations are ever sufficiently depressed by the predators to alleviate their influence on conifer seed. Moderate rodent populations are usually sufficient to consume large amounts of seed, and these or even higher levels are normally present in the forest to provide adequate food for the predators. It is unlikely, therefore, that encouraging natural or introduced predators will be of value in protecting conifer seed.

Disease.--At present, implantation of disease-causing organisms (e.g., bacteria and virus) to control seed-destroying agents does not appear promising. Artificial manipulation of disease involves many hazards to nontarget species. In addition, the potential development of genetic resistance to disease by the target animals would certainly limit the method's prospects of success.

Attractants and chemosterilants.--Poison baits could be improved by adding chemicals to attract target animals to the bait and antifertility agents to destroy the reproductive ability of survivors. Modern insect control methods use such chemicals, and the same approach certainly deserves consideration in seed protection.

Attractants and chemosterilants could also be used without poison, and thus eliminate the hazards associated with use of toxic chemicals. For example, recent laboratory and field investigations at the University of California show that mestranol, an antifertility agent, is promising in sterilizing deer mice and ground squirrels (Unpublished data). Hopefully, this chemical or other suitable compounds will be developed for field use soon.

Cultural Methods

Cultural seeding practices, such as time of seeding, could provide conifer seed with some protection. Such methods should be evaluated separately and in combination with other methods of control.

New Approaches

The importance of chemicals which occur naturally in seeds cannot be overemphasized. Such chemicals could provide new protection methods in the future. Howard and Cole (1967) have recently demonstrated that deer mice detect conifer seed by the smell of chemicals present in the seed. Possibly, then, the odorous components of the seed could be extracted and discarded or masked with other chemicals to make the seed undetectable by rodents. Similarly, as our knowledge of chemical factors that affect preferences of rodents and birds for seed increases, the application of naturally occurring compounds as repellents will be possible (Radwan 1969). Such compounds are likely to be safer and more effective than synthetic chemicals.

CONCLUSIONS

An extensive literature identifies many biotic agents which destroy conifer seed and thereby seriously interfere with natural and artificial reforestation. Although it is generally believed that seed-eating rodents and birds are the major problem agents, the extent of damage by the various pests is still unknown since methods to accurately assess seed losses are not available. Surely development of such methods is now needed so that appropriate control measures can be applied as required.

Methods now available to control seed-destroying agents are mostly inadequate. High costs of mechanical barriers rule them out on the millions of acres of forest land under consideration. Some help can be expected from cultural methods, but such measures will probably give seed adequate protection only when used in combination with other controls.

Clearly, the chemical approach is the most promising for satisfactory protection of conifer seed. So far, methods for poison baiting and treatment of seed with chemicals have been only partially successful, largely because of inadequate documentation of the basis for formulations and rates of application, and meaningful guidelines for use under different conditons. Research to improve these methods, therefore, is definitely needed to replace some of the chemicals now in use with safer compounds.

Research on new chemical approaches to the problem should also be encouraged. Work with synthetic attractants and chemosterilants, and with naturally occurring chemicals should, in time, yield safer, more effective control methods than are now available.

Developing chemicals for protecting conifer seed is highly complex. Success will undoubtedly depend largely on many talents, cooperation between agencies engaged in such research, and, more importantly, the understanding and cooperation of field foresters.

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