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REVIEW OF ANIMAL REPELLENTS

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INTRODUCTION

A review of the literature on this subject reveals there is considerable confusion regarding the meaning of the word "repellent" as it relates to animal control. Some people make a liberal interpretation and include any material or device that will alter the pattern of activity of an animal through response to sight, sound, taste, odor, or touch. Although such an interpretation may be valid, for this paper I would like to confine my discussion to "chemical repellents" -- materials that, when applied to seeds, plants, or other materials being damaged by animals, will reduce depredation through taste, odor, or possibly irritation.

The idea of using distasteful or foul-smelling materials to prevent losses from animals is not new and probably goes back to antiquity. Since World War II, however, increased importance has been placed on this method of "control", and research has been stepped up in recent years in an effort to develop more effective and useful materials to reduce losses by rodents, deer, rabbits, birds, and other animals that damage orchards, agricultural crops, and forest seeds and seedlings, and by commensal rats and mice that damage food packages, textiles, and other materials of economic importance. As many of you know, the Denver Center has played an important part in this work.

Much of this research has been made possible through continuing grants from the U. S. Army. The Army's Electronics Command recently increased its support to speed up research on protecting cable from rodents because of damage being experienced in Vietnam.

The search for chemical repellents also gained ground as a result of the recommendations of the Leopold Report, which stated, "We further recommend that the [Bureau's] research program shift some of its attention from methods of killing animals to ways of preventing depredations by repelling, excluding, or frightening animals." To accomplish this, major changes have been made in our chemical screening and development program, and the outlook for improved contact repellents looks promising (Kverno et al., 1965).

CHEMICAL SCREENING

This program, as now conceived, provides not only for the development of lethal agents that are specific for target species, but also the discovery of chemicals having a broad-spectrum repellency, effective against rodents, birds, and larger herbivores. In carrying out this work, candidate compounds solicited from cooperating chemical companies are first bioassayed in the laboratory at Denver to determine their toxicity and repellency to a standard series of test animals. Those materials that pass the initial screening trials are tested against target species (deer, mountain beaver, hares, etc.) in outdoor enclosures at the Olympia, Washington, substation, and the compounds that show up well in these trials are field tested in problem areas. The three-phase testing program for any successful chemical requires 3 years.

Compounds received 1 to 2 years ago that have shown desirable repellent characteristics are now in the advanced evaluation stages. To illustrate: during the past year, 293 experimental compounds received from nine different chemical companies were evaluated in 350 separate bioassay tests to determine biological activity. Twenty-one exhibited sufficient repellency to warrant pen testing on deer and hare at Olympia. It is anticipated that five to eight will be active enough to warrant field trials and will be evaluated against deer, elk, and hares in Washington, Oregon, and other states where they are a problem. Those chemicals found effective in field trials will then be tested on other animal pest species for which the use of repellents is practical.

As can be imagined, information collected in the screening program is voluminous, and storage and retrieval are most important if it is to be meaningful and useful. A storage and retrieval system employing a data-recording method suitable for computer analysis has recently been developed at the Denver Center (Loveless et al., 1966). This system uses printed Optical Mark Page Reader forms with the data recorded in such a manner that they are immediately convertible to machine language on an IBM 1230 series Optical Mark Page Reader. They can then be rapidly retrieved and printouts provided in tabular form so that results with the chemicals can be analyzed and decisions arrived at with a minimum of delay. We are encouraged by this approach and have every reason to believe that more effective repellent materials will be discovered with this program.

PACKAGING STUDIES

In discussing our work on repellents for packaging, I should like to make it clear that we recognize that the most satisfactory method of preventing these losses is through reductional control of commensal rodent populations, and through rodent-proof construction. However, such methods may not be completely successful in all cases and may be impossible or impractical to carry out under many conditions. The supplementary use of rodent-repellent containers or materials is therefore often advantageous.

In a paper published in 1954, I outlined the procedure by which chemicals were being evaluated as packaging repellents and detailed some of the problems, other than lack of rodent repellency, that prevented some of them from being used. Among these were toxicity, objectionable odor, instability, and high cost.

Over 8500 chemicals have now been tested by the Denver and Patuxent Research Centers, and still no suitable repellent for packaging has been found. Compounds showing a high degree of repellency such as beta-nitrostyrene (BNS) and tributyltin acetate (TBTA) have been extensively tested (Tigner, 1966) but for one reason or another have been eliminated. Beta-nitrostyrene is highly volatile, and efforts to stabilize it have failed. TBTA, though stable, did not provide sufficient protection of tarps and bags from Norway rats in tests to warrant its use over extended periods.

The results of the extensive studies to find a suitable packaging repellent are now being compiled, and publication is planned in 1968. Although no effective packaging repellent has been found, the information obtained from these studies has proved helpful in developing three effective repellents for preventing damage by field mammals (Besser et al., 1959). These are trinitrobenzene-aniline (TNBA), zinc dimethyldithiocarbamate cyclohexylamine (ZAC), and tetramethyl thiuram disulphide (TMTD), all of which are commercially available, highly effective in protecting woody plants from rabbits, and useful in protecting plants from mammals such as deer, rabbits, meadow mice, beaver, and livestock.

CABLE STUDIES

Studies to reduce animal damage to wire and cable are currently being emphasized at the Denver Center (Tigner et al., 1965). An organic tin formulation that has recently been prepared by an eastern chemical firm under a contract with the Denver Center shows considerable promise as a communication-wire protectant and is presently being field tested. The requirements of a candidate chemical for protecting materials of this type are much less rigid than for application to food containers. Toxicity and odor are of less concern as long as the compound can be applied so that its use does not create hazards in storage or handling of the finished product. It must, however, be sufficiently stable to ensure continued effectiveness under varied conditions.

Investigations now underway indicate that pocket gopher damage to underground telephone cable may be minimized by repellent treatment of the soil. A chemical known commercially as R-55 has given initial indications of good repellency. A large-scale field test now underway, involving some 60 miles of telephone cable, should answer many questions about this material.

Up to now the best protection has been afforded by mechanical means such as a stainless steel tape wrap, hardware cloth, or a paint containing ground glass or sand. The need for protective materials of this type is obvious, and we are continually being called on to provide assistance in this area. Only recently we were asked to supply information on the prevention of damage to electrical wires in helicopters operating in Vietnam. Rats have been finding harborage in these machines and have caused electrical failures. Rats also are posing problems at mobile field hospitals, where they damage flexible plastic tubing employed in the air conditioning system. To perfect effective and practical materials for such purposes is the aim of this program.

AREA REPELLENTS

The use of area repellents to control damage by animal pests has not met with much success. Compounds such as sodium si1icofluoride, lye, creosote, and lime sulfur have been used in runways and burrows of rats to discourage activity. Nicotine sulfate, oil of citronella, coal tar, and a variety of other substances have also been mentioned as objectionable to these animals.

In warehouses and similar structures where sacked grain is stored, a liberal application of powdered sulfur or flake naphthalene scattered over the bags has been found beneficial in reducing rat and mouse damage. Tests at Denver (Tigner et al., 1964) with a tear gas, chloropicrin, has also shown some promise in situations of this kind. At high concentrations the gas is lethal, but at lower levels it reduces activity or causes abandonment of the area. In these studies the area-repellent effect was observed, but the toxic effects of the gas were more pronounced. Even at low concentrations, chloropicrin cannot be used in areas where people are working, because of its toxic and irritating properties.

The use of area repellents has also found little application in minimizing damage by deer and other animals. Dried blood, predator animal scents, old shoes, and a myriad of other concoctions applied to rags or other materials and exposed in trees as area repellents have met with little success. Even chloropicrin slowly released in an orchard over a period of time from pressurized containers failed to prevent deer from rubbing their antlers on orchard trees.

CONTACT REPELLENTS

Damage by field rodents and other native wildlife to agriculture and forests is of considerable economic importance. The loss to forestation alone is estimated to be about 12 to 15 million dollars annually. The principal offenders are rabbits, field mice, tree squirrels, porcupines, and deer—creatures that feed on agricultural crops, seed, and seedlings in reforestation projects, shelterbelts, and orchards.

As in commensal rodent control, the application of repellents to solve these problems has limitations. Where reduction in animal populations may be prohibited by law, as in the case of deer and cottontail rabbits, or where reductional control is undesirable, repellents may be found useful.

The application of chemical repellents directly to trees, gardens, and other agricultural crops has met with appreciable success, as you know.

Rabbits and Deer

The search for chemical repellents for rabbits was undertaken even before World War 11. During that period a formulation known as 96-A was developed, which contained lime sulfur and copper salts as the active ingredients. When applied to the bark of dormant trees and coniferous seedlings, this material was effective in preventing damage by rabbits. It has a number of limitations, however, and was replaced with more effective materials having broader application. As mentioned earlier, these are ZAC, TMTD, and TNBA. These repellents have been used extensively in the forest industry to protect coniferous transplants from hare damage. At present most of the Douglas-fir seedlings planted in the Northwest are sprayed with TMTD in the nursery bed (Duffield et al., 1962), at an average of 10 gallons of spray to 1000 square feet of seed bed. Cost of applying TMTD is about 60 cents per thousand (2+0) trees, or roughly $3 per gallon of formulated spray.

These three repellents also continue to give excellent results in protecting deciduous trees from damage by cottontails and jackrabbits. They have provided satisfactory protection for all species of deciduous trees found in shelterbelts and qame-cover plantings. Good results have also been obtained when they are used on orchard trees.

Attempts to protect haystacks from rabbit depredations through repellents have not met with much success. The treatment is peripheral, and the protective barrier provided by the repellent, which is sprayed on the outside surface of the stack, is soon penetrated by the animals, giving them access to untreated hay and rendering the repellent treatment of little value. Protective wraps such as canvas or 1-inch mesh poultry wire have proved much more effective.

Deer, like rabbits, damage forest plantations, young orchard trees, and garden crops. Although a large number of materials have been tested, the ZAC and TMTD formulations continue to be the most effective. Protection, however, varies with the length of time, species of tree, thoroughness of treatment, and amount of deer pressure. The variation in reaction of an individual deer to these repellents may outweigh any of these factors.

Mice and Other Small Mammals

As most of you know, forest rodents, particularly white-footed mice (Peromyscus), cause considerable damage to forest seeds and are often the limiting factor in the regeneration of forest stands by direct seeding. Attempts to prevent this damage through use of repellents has met with limited success, but protection has been afforded by coating the seed with a 1-percent endrin formulation (Kverno, 1964). This treatment, which causes the animals to avoid the seed, has been most effective in the Northwest when applied to Douglas-fir seeds. In the pine regions, baiting with rodenticides has been found necessary to remove chipmunks and other large rodents that are less responsive to the endrin treatment.

Although damage to trees and agricultural crops by field mice and other rodents assumes considerable proportions at times, limited use has been made of repellents as a control measure. In some areas both TMTD and ZAC have shown promise in protecting Douglas-fir seedlings from damage by meadow mice. In other areas the results have not been so encouraging.

In Massachusetts, Dodge (1959) found that the highly active commensal rodent repellent BNS effectively repelled porcupines. This compound was 75-95 percent effective in preventing these animals from feeding on test materials and kept them from damaging outdoor structures. Eighteen materials tested, including TNBA, ZAC, and TMTD, were not nearly as effective.

Birds

Work at the Denver Center on bird repellents goes back to 1941 (Kalmbach et al., 1946), when color was found to discourage birds from taking poisoned grains exposed for rodent control. Green and yellow were most effective. This technique, however, is useful for only short periods, as birds quickly become aware of food items unnaturally colored and break through the barrier.

Another significant advancement was the development of repellent coatings for seed-eating birds in Louisiana where direct seeding of longleaf pine had failed (Mann et al., 1956). Both an anthraquinone compound and TMTD were found highly effective in minimizing depredations. When applied to field crops, however, these and other compounds tested have serious shortcomings because of the high concentration required to obtain effective repellency. From 20 to 50 pounds of TMTD in 65 to 140 gallons of spray is required per acre to approach an effective treatment.

A program of evaluating compounds for bird repellency has been underway at the Denver Center for a number of years. Recently modifications in the procedure have been made (Starr et al., 1964), and only compounds having high activity and low toxicity are considered for field evaluation. At present about 200 chemicals are tested a year and 5 to 10 of them can be expected to possess enough activity to warrant further testing. From the results of this work it appears that odor plays little part in repelling or deterring birds. Taste may be more important. The more effective compounds have been those producing some type of physiological reaction in the bird itself; frequently they are some what toxic to the test species.

Of the compounds being given advanced testing, the one that shows the most promise is DRC-736. In 2 years of field trials in South Dakota, this material has been found about twice as effective as TMTD in preventing pheasant damage to sprouting corn. Hopefully this and other compounds now being considered will become available to the general public for bird damage control.

To conclude, I should like to point out that wild animals, like people, are quick to adapt themselves to changing conditions, particularly if their survival is at stake. The protection afforded agricultural crops and other material by a repellent is dependent largely on the availability of other sources of food. Where these are scarce, protection with repellents is difficult and may fail. Under normal conditions, however, substantial protection can be maintained.

With the ever-growing infringement of civilization on the environment and the increased concern about pesticides and their effects on both man and wildlife, the need for developing chemicals of low hazard is apparent. Repellents normally provide such safeguards. Increased research in this area of animal control is vital if we are to meet our responsibilities to the public.

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