RODENT REPELLENTS FOR PLANTED GRAIN

RON J. JOHNSON and ANN E. KOEHLER, Department of Forestry, Fisheries and Wildlife

ORVIN C. BURNSIDE, Department of Agronomy, Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln, Nebraska 68583

ABSTRACT: Thirteen-lined ground squirrels (Spermophilus tridecemlineatus) and other small rodents damage corn (Zea mays) stands by digging and consuming planted seeds and young seedlings, particularly in reduced-tillage fields. The use of reduced-tillage systems such as ecofarming provides greater dryland crop yields, conserves moisture, reduces soil erosion and provides suitable habitat for ground-nesting birds. The habitat available in these fields also allows various species of rodents to thrive. Reduced-tillage farming is expected to increase markedly in the years ahead; thus, rodent problems will increase as well. Seed repellents offer a promising and cost-effective method of controlling rodent damage to planted corn in some areas. This paper reviews repellents for this use and describes repellency studies currently in progress with the compounds methiocarb [3,5-dimethyl-4-(methylthio) phenol methylcarbamate] and thiram (tetramethylthiuram disulfide).

INTRODUCTION

Various rodents cause damage to corn and other grains by digging and consuming newly planted seeds and young seedlings. This problem is not new but is increasing as we move towards reduced-tillage crop production systems. Thirteen-lined ground squirrel depredation to newly planted corn was reported in Iowa in 1889 and 1925 (Gillette 1889, Fitzpatrick 1925) and in South Dakota in 1892 (Orcutt and Aldrich 1892). Damage occurred in the past primarily at the edges of fields where rodent habitat was available.

The onset of mechanized agriculture in the 1940s and 1950s resulted in larger crop fields. Soils received more tillage which destroyed rodent cover and their burrows. These larger fields also had less edge habitat for rodents and thus there were fewer problems with rodent depredation to planted grain. Reports of such problems with rodents diminished in the literature. However, during the 1960s and 1970s, reduced-tillage agricultural systems were developed, and these have gained increased acceptance and use (USDA 1975). There are many types of reduced-tillage systems that vary with such factors as the crops planted, the crop rotation used, the geographical location, and the extent of tillage reduction. The reduction in tillage provides burrowing habitat, and plant residues which remain on the soil surface provide other needs that allow various species of rodents to thrive.

One reduced-tillage system, ecofarming, was developed in Kansas (Phillips 1964) and was initiated as a farming practice in Nebraska in 1973 (Wicks 1976). Ecofarming is a system of controlling weeds and managing plant residues throughout a cropping sequence with minimum or no tillage (Burnside et al. 1980). Reduced soil disturbance prevents establishment of many weeds; other weeds are controlled with herbicides.

Ecofarming has several advantages which are similar in other forms of minimum tillage. These advantages include decreased energy inputs for tillage, reduced soil erosion, improved moisture conservations, and increased and more stable non-irrigated crop yields (Fenster et al. 1973, Wicks and Smika 1973, Fenster and Wicks 1977). In addition, plant residues on the soil surface provide habitat for ground-nesting birds (Fenster and Wicks 1977, Nason 1981) such as pheasants (Phasianus colchicus), mallards (Anas platyrhynchos), meadowlarks (Sturnella spp.), and mourning doves (Zenaida macroura). In Nebraska, ecofarming acreage has increased from 200 acres in 1973 to 350,000 in 1982 (Wicks 1982).

Ecofarming and other forms of reduced tillage are likely to increase as energy costs and soil and water conservation influence agricultural practices. The USDA projects that by the year 2010, 95% of crop production in the U.S. will be some form of reduced tillage, and 55% will be no tillage (USDA 1975). Rodent problems will increase along with increases in reduced-tillage and especially no-tillage farming.

DAMAGE

Rodent depredation to newly planted grain has recently been reported in several states; the damaging species include thirteen-lined ground squirrels, kangaroo rats (Dipodomys spp.), and voles (Microtus spp.). Other small rodent species have been present in some fields and also may have caused damage (Table 1). Stand counts in Iowa cornfields with rodent depredation showed losses as high as 25% of the stand (R. Moorman, personal communication). Replanting has been necessary in portions of some fields in Iowa and Ohio (R. Moorman, personal communication, T. Stockdale, personal communication). In Nebraska, the problem is associated primarily with thirteen-lined ground squirrels in ecofarming fields, although some problems occur with kangaroo rats in reduced-tillage sandy areas.

Planting date affects the amount of damage caused by thirteen-lined ground squirrels. Corn plots planted at the Lincoln Agronomy Farm on 1 May 1976 had 20% stand loss, those planted on 15 May 80% loss, and those planted on 30 May 99% loss.

1982. Proceedings Tenth Vertebrate Pest Conference
(R.E. Marsh, Ed.), Univ. of California, Davis, Calif.

Table 1. Reported rodent depredation to newly planted seeds in reduced- or no-tillage cornfields.

State	Species	Source
Colorado	Dipodomys spp.	M. Boddicker, pers. commun.
Illinois	Microtus spp.* Synaptomys cooperi Peromyscus spp. Mus musculus	Beasley and McKibben 1976
Iowa	S. tridecemlineatus	R. Moorman, pers. commun.
Kansas	S. tridecemlineatus Dipodomys spp.	R. Henderson, pers. commun.
Nebraska	S. tridecemlineatus D. ordi	Fenster and Wicks 1977; Nason 1981, pers. observ.
Ohio	Microtus spp.	T. Stockdale, pers. commun.
Tennessee	Mice (probably Microtus spp.)	J. Byford, pers. commun.

*These four species were reported present in fields where damaged occurred.

CONTROL

Controls Available

Methods available to control depredation to newly planted grain include mechanical destruction of habitat or burrows, adjusting the planting date, shooting, trapping, alternate feeding, toxic baits, and repellents. Using an earlier planting date, where feasible, may reduce damage by some rodents. Shooting and trapping are generally not effective or practical in large field situations. Alternate feeding (e.g. scattering extra corn near rodent burrows at planting time) has reportedly worked in some situations but not in others; this method has not been adequately tested. Toxicants registered for rodent control in newly planted grain will vary among states, but they may include strychnine, Compound 1080, and zinc phosphide. In Nebraska, strychnine is the only toxicant with a registration that permits use for ground squirrel control in newly planted grain. However, the use of strychnine and zinc phosphide in reduced-tillage areas has resulted in concern about hazards to nontarget species, particularly ground-feeding birds (Beasley and McKibben 1976, Nason 1981). Toxicants and other control methods mentioned are all useful techniques at times, and should be available when needed. However, in newly planted grain fields, repellents offer an alternative that may be a more satisfactory control method.

Repellents

In this paper, repellents refer to substances that decrease the attractiveness of a food source to a target species. A repellent may make the food distasteful and/or cause disagreeable post-ingestion effects (Hermann and Kolbe 1971, Rogers 1974, 1978) which result in a conditioned aversion. Dorrance and Gilbert (1977) define aversive conditioning as "...a specialized form of learning that involves pairing a food, space, or an event with a painful experience or other negative reinforcer which leads to an avoidance of that item in subsequent encounters." Rogers (1978) points out that evolved chemical defenses of plants against herbivores generally function through conditioned aversion; the plant may not taste bad initially, but it causes an adverse physiological reaction that the target animal then associates with the taste or other aspect of the plant. Rogers (1978) suggests that conditioned aversion is the mode of action most likely to produce effective repellency in man-made repellents.

Repellent use on seeds may have several advantages. Because they are nonlethal, repellents may receive better public acceptance (Kellert 1979, Schmidt and Bruner 1981). They are target-specific; only animals that taste or consume treated grain would be affected. They are generally safe to nontargets; accidental ingestion generally is not lethal. Repellent use may be less time-consuming than some other controls, particularly if the repellent could be added by the seed supplier.

Another suggested advantage of repellent use is that a population within an area learns to avoid a treated food source; their presence during the critical period may prevent an immigration of "untrained" individuals of that species (Hermann and Kolbe 1971, Rogers 1978). In addition, the food habits of non-corn-eating rodents in the field may be beneficial. Beasley and McKibben (1976) point out that voles and mice consume weed seeds and seedlings which compete with corn. The diet of thirteen-lined ground squirrels is about half plant material and half invertebrates, particularly grasshoppers (Martin et al. 1951). Cutworms and wireworms are also eaten (Gillette 1889, Orcutt and Aldrich 1892, Fitzpatrick 1925); these are harmful to newly planted corn.

Repellent use has some potential disadvantages. Generally, some corn will be consumed before the repellent is recognized and avoided; this is a minor disadvantage because of the limited consumption. Repellents may be effective only when adequate alternative foods are available (Rogers 1978). Because repellents are not lethal, rodents remain in the field where their presence may attract other unwanted predatory animals. Prairie rattlesnakes (Crotalus viridis) are commonly reported in ecofarming fields in Nebraska. Badgers (Taxidea taxus) may be attracted in some areas; badger digging can destroy corn plants and pose a hazard to farm machinery. Unlike repellents, toxicants and other lethal controls which reduce rodent populations may reduce this attractiveness to predators, at least temporarily until immigration or reproduction rebuilds the rodent population.

THE SEARCH FOR REPELLENTS

For years, man has searched for effective repellents to protect agricultural crops from wildlife depredation (Welch 1954, Hermann and Kolbe 1971, Rogers 1978). Much of this work has addressed the problem of mammal damage to trees and shrubs (Besser and Welch 1959, Weingartner and Cech 1974) or rodent depredation of seeds in reforestation seedings (Thompson 1953, Passof 1974, Campbell 1981). Recently, considerable repellent work has been done in response to bird depredation problems (Guarino 1972, Crase and DeHaven 1976, Schafer et al. 1977). However, research using repellents to prevent rodent depredation of newly planted grain has been limited.

Beasley and McKibben (1974, 1975, 1976) evaluated several control methods for rodent damage in newly planted zero-tillage corn. They tested methiocarb in four treatment levels, zinc phosphide broadcast and applied underground in the row, and removal of plant residues from the field. No statistical analysis was reported; however, the methiocarb and zinc phosphide treatments appeared comparable in reducing damage and showing associated increased yields. The one-year trial of removing plant residues from the soil surface resulted in damage reduction from 16% to 0. This method may control the species which were present in their fields. However, it may not control other species such as thirteen-lined ground squirrels that usually inhabit short-grass areas. In addition, Beasley and McKibben (1976) point out that vegetation removal risks losing moisture that is critical to the success of zero-tillage agriculture in some soil types. Mechanical vegetation removal also risks increased soil loss through erosion.

During 1980, research was begun at the University of Nebraska to evaluate two promising repellents, methiocarb and thiram. Methiocarb is registered in the eastern United States as a bird repellent for application to corn seed, and it has a Special Local Needs (24-C) registration in some states as a rodent repellent for corn seed. Lefebvre (1978) found in laboratory feeding preference tests that methiocarb repelled fox squirrels (Sciurus niger). Thiram is registered as a fungicide and repellent. It has been used for protecting trees, tree seedlings, bulbs and other plant materials from damage by rodents and other mammals (Besser and Welch 1959, Welch 1967, Weingartner and Cech 1974).

Methiocarb and thiram repellency to ground squirrels was tested in laboratory feeding-preference trials using treated seed corn in 1980 (Zurcher et al., submitted) at the University of Nebraska, Lincoln. Methiocarb was tested at the label rate (0.5% by weight). Thiram was tested at the label rate (0.08% by weight) and at 2 and 4 times the label rate. Results showed that both methiocarb and thiram repelled ground squirrels at the concentrations tested. However, when offered only thiram-treated corn (0.08%) for 18 days, the test animals seemed unaffected and ate normal amounts; weight loss was not significant ($P > 0.05$). In a similar 18-day no-choice test with methiocarb (0.5%), the test animals ate minimal amounts and showed a significant weight loss ($P < 0.001$). When offered a choice of methiocarb-treated corn versus untreated corn, the squirrels ate minimal amounts and had significant weight loss ($P < 0.001$) even though untreated corn was readily available.

Zurcher et al. (submitted) suggested that although both chemicals repelled ground squirrels, methiocarb appeared to offer better efficacy than thiram at the dosages tested. They point out that further tests are needed to evaluate the laboratory results in the field and to determine proper dosages under field conditions. In addition, the economics of using these two repellents must be considered, and here thiram is favored.

CURRENT RESEARCH

We began field studies with methiocarb and thiram at the University of Nebraska during 1981. The objective of these studies was to determine the efficacy and feasibility of using repellents to protect planted corn seed from rodents. The techniques used included field plots, field-cage plots, and germination-chamber studies. Corn seeds were treated with methiocarb (0.5%, 2.5% or 5% by weight) or thiram (0.08%, 0.4% or 0.8% by weight). Untreated and thiram- or methiocarb-treated corn seeds were planted in field or field-cage plots in a randomized complete block design. The field-cage technique, originally developed for testing the repellency of various seed coatings to birds (Linehan 1979), was modified and used for repellency tests with ground squirrels. This method offers the advantage of having many variables controlled, yet the tests are done in a field situation and apparently stimulate natural field conditions. Data were collected on ground squirrel damage to corn, ground squirrel feeding pressure, and effects of treatments on corn growth. The germination-chamber studies examined treatment effects on early plant growth.

Initial results were promising. Although both compounds showed repellency under some conditions, methiocarb appeared to offer better control at the rates tested. However, at the rates tested, the thiram was considerably less expensive than the methiocarb. Higher rates of thiram may show effective repellency and be less expensive to use.

Field studies will be continued this year at Lincoln. Further data are needed on variations in weather, ground squirrel numbers, and other factors to be evaluated. Appropriate treatment rates for these repellents need to be determined.

More information is needed on rodents and other fauna throughout the year in reduced-tillage fields. For example, what are the relationships between rodents and predators such as rattlesnakes or badgers? What happens to rodent populations when corn grows high? To what extent do rodents consume cutworms, wireworms or other undesirable insects in cornfields? In addition, a better assessment of rodent damage in reduced-tillage corn is needed. Damage assessment would provide a better understanding of economic thresholds for initiating control measures.

CONCLUSION

Reduced-tillage agricultural systems provide an opportunity for deriving many benefits from sound animal damage control. Howard (1978) pointed out the substantial contributions that animal damage control workers make to both agriculture and nontarget wildlife. Their efforts provide control techniques that minimize impacts on nontarget species and which prevent the need for less desirable control alternatives such as habitat destruction. The success of reduced-tillage systems depends in part on finding appropriate solutions to rodent damage problems. Seed repellents offer a promising method to help achieve this goal.

ACKNOWLEDGMENTS

We thank M. Beck, R. Case and R. Timm for helpful comments on this manuscript and are grateful to J. Andelt and S. Lohmeier for typing and proofreading. Current research is supported by a grant from the North Central Regional Pesticide Impact Assessment Program and the National Agricultural Pesticide Impact Assessment Program of the U.S. Department of Agriculture.

LITERATURE CITED

BEASLEY, L.E., and G.E. MC KIBBEN. 1974. Controls for mouse damage in no-till corn. Illinois Agric. Exp. Sta., Dixon Springs Agric. Center, Simpson, Illinois. DSAC 2:59-60.

__________. 1975. Controls for mouse damage in no-till corn. Illinois Agric. Exp. Sta., Dixon Springs Agric. Center, Simpson, Illinois. DSAC 3:96.

__________. 1976. Mouse control in no-till corn. Illinois Agric. Exp. Sta., Dixon Springs Agric. Center, Simpson, Illinois. DSAC 4:27-30.

BESSER, J.F., and J.F. WELCH. 1959. Chemical repellents for the control of mammal damage to plants. Trans. North Am. Wildl. Conf. 24:166-173.

BURNSIDE, O.C., G.A. WICKS, and D.R. CARLSON. 1980. Control of weeds in an oat (Avena sativa) - soybean (Glycine max) ecofarming rotation. Weed Sci. 28:46-50.

CAMPBELL, T.E. 1981. Effects of endrin in repellent seed coatings on caged rodents. USDA Forest Serv., Southern Forest Exp. Sta., New Orleans, Louisiana. Research Paper SO-174. 4pp.

CRASE, F.T., and R.W. DE HAVEN. 1976. Methiocarb: its current status as a bird repellent. Pages 46-50 In Proc. Seventh Vertebr. Pest Conf., Monterey, CA, March 9-11, 1976 (C.C. Siebe, ed.), Publ. University of California, Davis.

DORRANCE, M.J., and B.K. GILBERT. 1977. Considerations in the application of aversive conditioning. Pages 136-144 In W.B. Jackson and R.E. Marsh, eds., Test Methods for Vertebrate Pest Control and Management Materials, ASTM STP 625, American Society for Testing and Materials.

FENSTER, C.R., and G.A. WICKS. 1977. Minimum tillage fallow systems for reducing wind erosion. Trans. ASAE 20(5):906-910.

__________ and D.E. SMIKA. 1973. The role of ecofallow for reducing energy requirements for crop production. Absts. Am. Soc. Agron. 64:122.

FITZPATRICK, F.L. 1925. The ecology and economic status of Citellus tridecemlineatus. University of Iowa Studies in Natural History, Iowa City, Iowa. New Series No. 86. 11(1):3-40.

GILLETTE, C.P. 1889. Food habits of the striped prairie squirrel. Iowa Agric. Exp. Sta., Ames, Iowa. Bull. No. 6. pp. 241-244.

GUARINO, J.L. 1972. Methiocarb, a chemical bird repellent: a review of its effectiveness on crops. Pages 108-111 In Proc. Fifth Vertebr. Pest Conf., Fresno, CA, March 7-9, 1972 (R.E. Marsh, ed.), Publ. University of California, Davis.

HERMANN, B., and W. KOLBE. 1971. Effect of seed coating with Mesurol for protection of seed and sprouting maize against bird damage, with consideration to varietal tolerance and side-effects. Pflanzenschutz-Nachr. 24(2):279-320.

HOWARD, W.E. 1978. Opening comments -- Eighth Vertebrate Pest Conference -- and the stability of vertebrate populations in man-modified habitats. Pages 1-2 In Proc. Eighth Vertebr. Pest Conf., Sacramento, CA, March 7-9, 1978 (W.E. Howard, ed.), Publ. University of California, Davis.

KELLERT, S.R. 1979. Public attitudes toward critical wildlife and natural habitat issues; Phase I, U.S. Dept. of Interior, Fish and Wildl. Serv., Yale School of Forestry and Environmental Studies, New Haven, Connecticut. 138 pp.

LEFEBVRE, L.W. 1978. Repellency of methiocarb-treated corn seed to fox squirrels. Wildl. Soc. Bull. 6:231-234.

LINEHAN, J.T. 1979. Improving efficacy testing of bird-repellent seed treatments. Pages 217-230 In J.F. Beck, ed., Vertebrate Pest Control and Management Materials, ASTM STP 680, American Society for Testing and Materials.

MARTIN, A.C., H.S. ZIM, and A.L. NELSON. 1951. American wildlife and plants, a guide to wildlife food habits. Dover Publ., Inc., New York, New York. 500 pp.

NASON, G. 1981. Ecofallow and game birds. Pages 1-2 In R.N. Klein, ed., Proc. Ecofallow Conf., Coop.Ext.Serv., Institute of Agric. and Nat. Res., University of Nebraska-Lincoln.

ORCUTT, I.H., and J.M. ALDRICH. 1892. Food habits of the striped gopher. South Dakota Agric. Coll. and Exp. Sta., Bull. No. 30. pp. 8-11.

PASSOF, P.C. 1974. Rodent control activities when direct seeding forest lands in Northern California. Pages 127-131 In Proc. Sixth Vertebr. Pest Conf., Anaheim, CA, March 5-7, 1974 (W.V. Johnson, ed.), Publ. University of California, Davis.

PHILLIPS, W.M. 1964. A new technique of controlling weeds in sorghum in a wheat-sorghum-fallow rotation in the Great Plains. Weed Sci. 12:42-44.

ROGERS, J.G., JR. 1974. Responses of caged red-winged blackbirds to two types of repellents. J. Wildl. Manage. 38:418-423.

_____________. 1978. Repellents to protect crops from vertebrate pests: some considerations for their use and development. ACS Symposium Series, No. 67, Flavor Chemistry of Animal Foods, R.W. Bullard, ed. pp. 150-165.

SCHAFER, E.W., JR., R.B. BRUNTON, and N.F. LOCKYER. 1977. Learned aversion in wild birds: A method for testing comparative acute repellency. Pages 186-194 In W.B. Jackson and R.E. Marsh, eds. Test Methods for Vertebrate Pest Control and Management Materials, ASTM STP 625, American Society for Testing and Materials.

SCHMIDT, R.H., and J.G. BRUNER. 1981. A professional attitude toward humaneness. Wildl. Soc. Bull. 9:289-291.

THOMPSON, H.V. 1953. The use of repellents for preventing mammal and bird damage to trees and seed. Forestry Abstr. 14(2):129-136.

U.S. DEPARTMENT OF AGRICULTURE. 1975. Minimum tillage: a preliminary technology assessment. Office of Planning and Evaluation, Washington, D.C. 34 pp.

WEINGARTNER, D.H., and F.C. CECH. 1974. Screening materials for rodent repellency. Proc. West Virginia Acad. Sci. 46(1):27-34.

WELCH, J.F. 1954. Rodent control, a review of chemical repellents for rodents. J. of Agric. and Food Chem. 2:142-149.

_________. 1967. Review of animal repellents. Pages 36-40 In Proc. Third Vertebr. Pest Conf., San Francisco, CA, March 7-9, 1967, Publ. University of California, Davis.

WICKS, G.A. 1976. Ecofallow: a reduced tillage system for the Great Plains. Weeds Today 7:20-23.

_________. 1982. Status of ecofallow in the winter wheat-corn or sorghum-fallow rotation. Pages bl-3 In Proc. Ecofallow Conf., Coop.Ext.Serv., Institute of Agric. and Nat. Res., University of Nebraska-Lincoln.

_________ and D.E. SMIKA. 1973. Chemical fallow in a winter wheat-fallow rotation. Weed Sci. 21: 97-102.

ZURCHER, N.J., R.J. JOHNSON, and R.M. TIMM. Methiocarb and thiram as corn seed repellents for thirteen-lined ground squirrels. (submitted for publication).