BIRD DAMAGE CONTROL: ARE CHEMICAL REPELLENTS THE ANSWER?

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ABSTRACT.

Birds cause extensive damage to many agricultural crops, and most currently used methods for reducing this damage are unsatisfactory. Recent interest has focused on the use of chemical repellents which, if effective, could protect crops while having minimal adverse impacts on pest birds and other, non-target animals. However, while repellents may provide relief from depredating birds in some situations, they are not the solution to all of our bird problems. The effectiveness of chemical repellents is influenced by biological factors such as the physiology of the pest animal, its hunger and motivational state, individual behavior, and social interactions. The characteristics of the food to be protected and the phenology of the crop also influence efficacy. The amount of chemical residues remaining on the crop at harvest, impacts on non-target animals, adverse effects on the growth and development of the crop and, finally, the cost of using the repellent versus the benefits to be derived all determine whether or not a repellent will be used successfully. A hypothetical idealized crop-bird complex is described for which chemical repellents should be most effective for reducing bird damage.

INTRODUCTION

Agriculturalists have used a wide variety of methods to try to reduce economic losses caused by birds. Unfortunately, most attempts at damage reduction have met with only limited success. Netting or wire excludes birds from crops, but it is expensive and often interfers with normal farming operations. Attempts to reduce pest populations with traps, firearms, surfactants, avicides or chemosterilants are most effective when the offending birds congregate in small resident flocks. However, avian pests frequently congregate in large flocks and often are nomadic or migratory. Modification of the habitat by controlling weeds and brush, removing loafing areas, or altering roost sites can minimize the attraction of pest birds into an area, but such methods are the least selective control methods because of the wide variety of non-target species affected. Scare crows, hawk models, gas cannons, synthetic or recorded distress calls and other such devices may provide limited protection of short duration, but birds quickly become habituated to non-lethal frightening agents unless actions are taken to reinforce them. Finally, chemical repellents may be applied to some crops to deter birds from feeding on them.

In theory, such repellents would seem like an ideal method for reducing bird depredations because they exploit the natural tendency of birds to avoid harmful or obnoxious foods and they are non-lethal. However, while chemical repellents may provide relief in some situations (Stone 1976; Bruggers 1979; DeHaven et al. 1979; Mason et al. 1985), protection has not always been satisfactory (Dambach and Leedy 1948; Wright 1962; Schemnitz et al. 1976; Feare et al. 1978; Crabb 1979; Joyner et al. 1980). Chemical repellents are not the solution to all of our bird problems. In this paper we discuss various factors that influence the efficacy of bird repellents and suggest the types of situations where they are most likely to be useful.

FACTORS INFLUENCING REPELLENCY

Biology and Behavior of the Pest Bird

Unlike avicides, bird repellents are intended to alter the feeding behavior of the target organisms, not kill them. Behavior is a complex phenomenon that comprises factors at several hierarchical levels, including physiological and motivational factors, individual behavior and learning ability, and social interactions among birds in a flock.

The strength of any repellent depends on the severity of the consequences of eating the food treated with that repellent: the more severe the consequences, the stronger and longer lasting the repellency (Alcock 1970a, b; Rogers 1974; Genovese and Browne 1978). Farmers and researchers historically have emphasized primary repellents which have a presumably obnoxious taste or smell (Neff and Meanley 1956), even though these senses are poorly developed in most birds. A mixture of garlic powder and cayenne pepper (Sevana Bird Repellent^{R}), copper oxalate (Crow-Chex^{R}), quazatine (Panoctine^{R}, Panolil^{R}), and synergized aluminum ammonium sulfate (SAAS, Curb^{R}) are examples of taste repellents. The problem with all of these primary repellents is that in severe situations where food is scarce, they provide only a weak deterrent to hungry birds (Luckwill and Weaver 1964; Rogers 1974). Increasingly, attention has focused on secondary repellents which have noxious or emetic postingestinal effects (Rogers 1978). Thiram (Arasan^{R}), ziram, endrin, dieldrin (Red Shield^{R}), lindane, endosulfan (Thiodan^{R}), anthraquinone, aldicarb (Temik^{R}), and methiocarb (Mesurol^{R}) all presumedly rely on postingestinal effects to repel birds.

Bird species vary in their susceptibility to repellents (Schafer and Brunton 1971), and the effective use of chemical repellents therefore often depends on the particular species causing damage. Tobin and DeHaven (1984) found that methiocarb was much more effective for protecting grapes from house finches (*Carpodacus mexicanus*) than from either European starlings (*Sturnus vulgaris*) or American robins (*Turdus migratorius*). Bruggers (1979) concluded that success with using synergized aluminum ammonium sulfate to protect ripening grains in Africa appears more likely when the pest species are bishops (*Euplectes spp.*), golden sparrows (*Passer luteus*), or black-headed weavers (*Ploceus spp.*) than quelea (*Quelea spp.*). Similar differences undoubtedly exist among many other bird species.

The motivational state of the depredating birds and the availability of alternative untreated foods also influence the protection afforded to repellent-treated crops. Hungry birds are more highly motivated to eat foods treated with a repellent. Extensive bird depredations usually occur because the crop is a highly preferred food for the bird. The objective of using a repellent is to lower the value of that food relative to other types of food available. However, when alternative foods are not available, repelling birds can be very difficult. Repellents may be least effective where they are needed most, where food is scarce and birds are under the most pressure to damage crops (Dyer 1976). Planting a lure crop or offering alternative untreated food may enhance repellency. Benjamini (1980) enhanced the repellency of treated sugar beet seedlings to chukar partridges (*Alectoris chukar*) and skylarks (*Alauda arvensis*) by planting inexpensive sugar beet seeds between rows of commercial plantings of sugar beets.

As more farmers in an area use a repellent, its efficacy may decline. Repellents often provide substantial protection where few fields are treated and birds can readily fly to untreated fields (Conover 1985). However, in such situations repellents may simply shift the damage from one field to another. Where a greater proportion of fields is treated, repellents may provide less protection.

Methods of foraging and feeding may influence the amount of repellent-treated food encountered and ingested. Dehaven and his colleagues (1979) suggested that repellents used to protect ripening cherries may be less effective against cedar waxwings (*Bombycilla cedrorum*) than other species because cedar waxwings tend to forage at the tops of the trees where spray coverage is poorest.

Techniques of manipulating and eating food determine how much repellent is actually ingested. Crabb (1979) found that methiocarb was ineffective in reducing the damage caused by European starlings and house finches in commercial fig orchards. Starlings pierce the thick skin of the fig and feed on the soft inner portions of the fruit. House finches tear off pieces of the skin and drop them to the ground, and then feed on the inner portions of the fig. Thus, both species ingest only small amounts of the repellent deposited on the skin of the fig. Other birds that damage figs feed in a similar manner and, as expected, are not deterred by topical repellents.

Birds like European starlings and American robins eat grapes by plucking and consuming entire berries. These birds consume most of any repellent deposited on the skin on the berries. Smaller birds like house finches and goldfinches (*Carduelis spp.*) usually peck holes in the skin of the grapes and eat only the insides of the berries. Birds which peck at the fruit may ingest less repellent than birds which pluck and swallow the entire fruit.

Similar effects may occur with seed eating birds (Neff and Meanley 1956). Doves, pigeons, quail, and pheasants normally swallow their food without hulling or manipulating it in their beaks. Repellents may affect these birds differently than passerine birds, which hull seeds before eating them.

A better understanding of how birds perceive and react to repellent treated foods could permit the development of more effective strategies for their use. Whether birds form aversions to feeding in certain areas or only to eating particular types of food will in part determine the most effective use of repellents for each situation. After encountering food treated with a repellent, some birds apparently avoid the entire area (Ingram et al. 1973; Stickley and Ingram 1973), and several authors have suggested that repellency is best where large plots are treated (West et al. 1969; Shumake et al. 1976; Benjamini 1981). However, other birds continue to feed in areas with repellent-treated crops, but on alternative food (Ingram et al. 1973; Rogers and Linehan 1977; Green 1980).

Where birds form area-wide aversions, treatments of only part of the field might provide protection for the entire crop. Treatment of the three rows along the border of each of three Australian vineyards protected the entire vineyards from bird damage (Bailey and Smith 1979). The major depredating bird species at these vineyards (*Turdus merula* and *Zosterops lateralis*) fed first on the perimeter of the field, and the authors cautioned that the particular partial treatments applied may not provide protection against all pest bird species or in areas where little alternative, untreated food is available. Dambach and Leedy (1948) observed that male ring-necked pheasants (*Phasianus colchicus*) tended to feed throughout corn fields in Ohio, while females foraged mostly on the perimeter of fields adjacent to nesting cover. Treatment of entire fields would probably be necessary to repel males, but treatment of borders only might suffice to repel females. In contrast, Joyner and his colleagues (1980) found that partial treatment with methiocarb did not deter blackbirds (Icteridae) from damaging maturing corn. Since various bird species forage differently, the most cost-effective treatment regime for a particular repellent may vary depending on the particular species of bird causing damage.

Auxiliary sensory cues have enhanced the repellency of food to captive birds (Bullard et al. 1983a, b; Mason and Reidinger 1983a, b; Rooke 1983; Avery 1985), but rarely has their use been extended to protection of commercial crops. Laboratory studies have indicated the importance of taste (Brett et al. 1976; Shumake et al. 1976), sight (Wilcoxin et al. 1971; Logue 1980), and location (Tobin 1985a, b) in food aversion learning with birds, but more studies are needed to determine which, if any, of these types of cues are most appropriate for use with each specific crop/bird interaction.

With most repellents, birds must damage part of the crop before they experience the adverse postingestinal consequences and are repelled (Rogers 1974). If all birds in a flock must ingest a repellent in order for an aversion to develop, birds may damage a substantial amount of the crop before they are repelled. However, most bird species that are significant agricultural pests are gregarious, and if aversions can be transmitted socially from one bird to another, a flock of birds might be repelled from a crop after only a few members of the flock ingest the repellent. Among some bird species, sociality facilitates the transfer of information about the location of food (Horn 1968; Ward and Zahavi 1973; Krebs 1974; Emlen and Demong 1975; DeGroot 1980) and about what foods are appropriate to eat (Rothschild and Ford 1968; Alcock 1969). Limited experiments have indicated that social facilitation among birds may also have implications for food aversion learning (Mason and Reidinger 1982; Mason et al. 1984). However, more studies are needed to evaluate the effects of gregariousness, social facilitation, and observational learning on repellency.

Characteristics of the Crop

For a repellent to be effective, the portion of the crop that is handled or consumed by the pest birds must be treated. Food items with thick skins, husks, hulls, or shells which birds can remove before eating are difficult to protect with chemical repellents. Repellents are of little use for protecting seed pods of cole crops because birds split pods open and remove seeds without consuming any of the pod. Sunflower seeds are also difficult to protect with topically applied repellents. Treatment of seeds on maturing sunflower heads is hampered by the way the seeds are inset in the flower head and by the fact that the heads droop, making treatment with conventional spray equipment difficult. Even if sunflower seeds could be treated, pest birds such as house finches break away the outer shell and eat the untreated seed within. Thick-skinned fruit is equally difficult to protect with chemical repellents because birds often consume the soft inner portions of the fruit while leaving the exterior skins (Crabb 1979). Repellents also offer little hope for reducing bird depredations to nut crops. Walnuts, almonds, and pistachios all have an unedible hull and shell protecting the edible portion of the nut, and many birds eat the inside nut while ingesting very little if any repellent applied to the outer hull.

Seed repellents may provide little protection after germination unless the repellent is absorbed into the growing seedling (Wright 1962). Birds that damage seedlings after the cotyledon has emerged may never touch the seed coat where the repellent was deposited. In such situations, systemic repellents are more likely to protect the seedlings.

The phenology of a crop also influences whether a chemical repellent controls depredating birds. Repellents are most effective in protecting crops that are susceptible to damage when the depredating birds are not migrating. When new birds continually migrate into an area, they presumably must sample the repellent treated crop before learning to avoid the treated food. As new migrants sample the crop, damage increases.

The length of time during which a crop requires protection is critical to the success of a chemical repellent. Crops that are susceptible to bird damage for only a few days are easier to protect with repellents than those crops that require protection for longer periods.

A primary factor that reduces the efficacy of repellents over time is the breakdown of the chemical residues of the repellents on crops (Moulton 1979). The specific rate of breakdown depends on the nature of the chemical and on the prevailing weather conditions.

The potential for any repellent to affect the growth of crops should be considered. Repellents that have received widespread use in the past for protecting germinating seeds, but have been shown to have phytotoxic effects include coal tar based substances (Dambach and Leedy 1948), anthraquinone (Wright 1962), and thiram (Mann et al. 1956; Wright 1962). Carefully controlled studies are necessary to separate the apparent benefits of a repellent from any possible deleterious effects it may have on crop development.

Ecological Factors

Residues of repellents on food crops are of concern because of potential hazards to humans, livestock, and the environment. Concerns about residues have led to a reevaluation of methiocarb as a repellent for protecting ripening fruit. The carcinogenicity of coal tars and phenolic materials has resulted in their discontinued use as bird repellents in the United States. The persistence of some organochlorine compounds and concern about long term ecological effects have resulted in the removal of endrin and dieldrin from use as bird repellents. Before any repellent can be registered, careful studies of residues remaining on the crop must be conducted. Nonetheless, fears persist among processors and consumers. Processors frequently require growers to provide a list of all pesticides that have been applied to the crop during the growing season. During years when a crop is in abundant supply (a buyer's market), processors may reject crops that have been treated with repellents (e.g., wineries sometimes refuse to purchase methiocarb-treated grapes). With nonfood crops, concerns sometimes exist about how residues might influence seed viability.

The impact of repellent treatments on other potential pests should also be considered. For example, the use of methiocarb and some other carbamate insecticides can disturb the balance between beneficial arthropods and the mite pests they control (Flaherty et al. 1969). Pest mite outbreaks frequently follow the use of carbamate insecticides with grapes and deciduous fruits. Monocultures are fragile ecosystems that are easily disrupted, and caution should be exercised before disturbing such systems further.

Economic Considerations

Perhaps the most important criterion concerning the usefulness of repellents involves economics. The utility of any repellent depends not only on the protection afforded by the repellent, but also on the costs of purchasing and applying the repellent (Dyer 1976, Bruggers 1979; Moulton 1979; Hothem et al. 1981; Somers et al. 1983). Figure 1 is a cost-benefit graph for methiocarb similar to that developed by Dolbeer (1981) for Avitrol^{R} and propane exploders. Hothem and his colleagues (1981) estimated to achieve approximately 65% reduction in bird damage to grapes using methiocarb, they had to apply an average of two treatments at a total cost we estimated to be \$312.00/ha. Duncan (1980) estimated to achieve approximately 40% reduction in damage to sorghum, he had to use three treatments of the repellent, which we estimated would cost \$375.00/ha. The slope of the cost-benefit line for each crop in Figure 1 reflects the estimated percent reduction in damage due to methiocarb. The horizontal line intersecting each cost-benefit line represents the cost of using the repellent for that crop. A vertical line drawn from this intersection down to the abscissa defines the break-even point for using the repellent on that crop. The break-even point for using methiocarb on grapes is \$240.00/ha (Table 1). If the anticipated damage is greater than this, one would be justified in using methiocarb. The break-even point for sorghum is \$937.50/ha. This analysis indicates that use of methiocarb is more easily justified for grapes than for sorghum. In general, use of repellents (or any damage reduction technique) is more easily justified for high value crops.

Table 1. Determine the break-even point where the anticipated reduction in damage is equal to the cost of the methiocarb treatment.

Crop	Cost of Methiocarb	Efficacy of Control	Loss (\$/ha) Required Before Control is Justified
Grapes	312.00	0.65	480.00
Sorghum	375.00	0.40	937.50

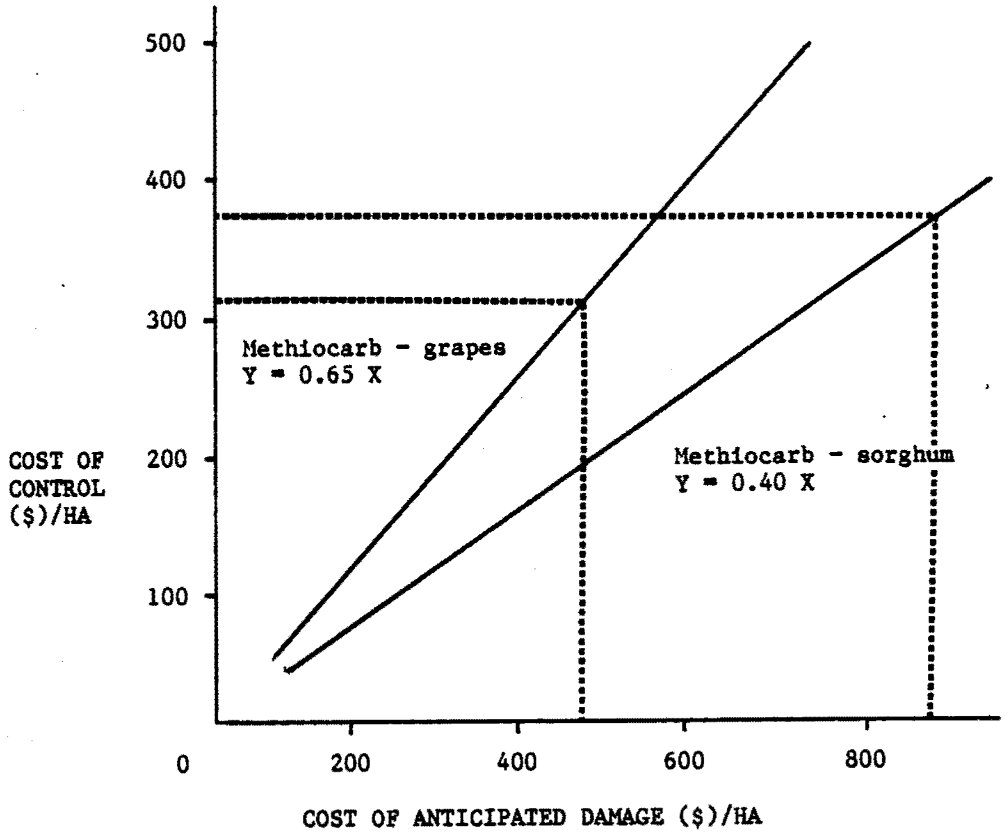

Figure 1. Cost-benefit equations for methiocarb based on reported reduction in bird damage to grapes (Hothem et al. 1981) and grain sorghum (Duncan 1980). Based on estimated costs of application and estimated levels of damage reduction, the break-even point for using methiocarb can be determined. To justify the use of this repellent, anticipated damage must be greater than $480.00/ha for grapes and greater than $937.50 for sorghum.

CONCLUSION

Chemical bird repellents may be useful in some situations, but not in others. A general understanding of the various factors that influence repellency can help define the types of situations where repellents are most likely to reduce damage by birds (Table 2). Repellents are likely to be most useful against resident species of birds damaging high value crops in areas where alternative, untreated foods are readily available. Repellents that produce noxious or emetic postingestinal effects in the target organism usually result in stronger and longer lasting aversions than repellents that merely have an obnoxious taste of smell. Repellents should have minimal effects on the crop itself and on non-target animals. Crops which maximize the chances of the birds ingesting the repellent and which require protection for only short periods are most amenable to protection by repellents. Chemical residues of repellents are most likely to persist for the duration of the period of damage susceptibility if weather conditions are dry. A comparison of the costs of purchasing and applying a repellent versus the expected reduction in bird damage is the ultimate criterion for determining the usefulness of any particular repellent.

Table 2. Factors that influence the efficacy of bird repellents.

Factor	Efficacy	
	Least Effective	Most Effective
Movements of birds during period of crop susceptibility	Migratory	Resident
Value of crop	Low	High
Alternate foods	Unavailable	Readily available
Mode of action	Primary repellent	Conditioned aversion
Effects on crop	Phytotoxic	Non-phytotoxic
Ecological effects	Nontarget poisoning	Selective
Exposure of repellent on crop	Low potential for ingestion	High potential for ingestion
Period of crop susceptibility	Long	Short
Persistence of repellent on crop	Short	Long
Weather conditions	Wet	Dry
Cost of using repellent	High	Low
Expected reduction in bird damage	Small	Great

LITERATURE CITED

Alcock, J. 1969. Observational learning in three species of birds. Ibis 111: 308-321.

________. 1970a. Punishment levels and the response of black-capped chickadees (*Parus atricapillus*) to three kinds of artificial seeds. Anim. Behav. 18: 592-599.

________. 1970b. Punishment levels and the response of white-throated sparrows (*Zonotrichia albicollis*) to three kinds of artificial models and mimics. Anim. Behav. 18: 733-739.

Avery, M. L. 1984. Relative importance of taste and vision in reducing bird damage to crops with methiocarb, a chemical repellent. Agric. Ecosyst. Environ. 11: 299-308.

Bailey, P. T., and G. Smith. 1979. Methiocarb as a bird repellent on wine grapes. Aust. J. Exp. Agric. Anim. Husb. 19: 247-250.

Benhamini, L. 1980. Bait crops and Mesurol sprays to reduce bird damage to sprouting sugar beets. Phytoparasitica 8: 151-161.

__________. 1981. The efficacy of seed treatment with aldicarb to establish condition aversion in birds to sprouting sugar beets. Phytoparasticia 9: 3-9.

Brett, L. P., W. G. Hankins, and J. Garcia. 1976. Prey-lithium aversions. III: Buteo hawks. Behav. Biol. 17: 87-98.

Bruggers, R. L. 1979. Evaluating Curb as a crop repellent to West African bird pests. Pages 188-197 in J. R. Beck (editor) Proc. 2nd Symp. on Test Methods for Verte. Pest Control and Manage. Mat. ASTM STP 680. Am. Soc. Testing and Mat., Philadelphia, PA.

Bullard, R. W., R. L. Bruggers, S. R. Kilburn, and L. A. Fiedler. 1983a. Sensory cue enhancement of the bird repellency of methiocarb. Crop Prot. 2: 387-398.

____________, E. W. Schafer, Jr., and R. L. Bruggers. 1983b. Tests of the enhancement of avian repellent chemicals with sensory cues. Pages 66-75 in D. E. Kaukeinen (editor) Proc. 4th Symp. on Test Methods for Verte. Pest Control and Manage. Mat. ASTM STP 817. Am. Soc. Testing. Mat., Philadelphia, PA.

Conover, M. R. 1985. Using conditioned food aversions to protect blueberries from birds: comparison of two carbamate repellents. Appl. Anim. Behav. Science 13: 383-386.

Crabb, A. C. 1979. A report on efficacy of methiocarb as an avian repellent in figs and results of industry-wide bird damage assessments. Pages 25-30 in W. B. Jackson (editor) Proc. 8th Bird Control Seminar. Bowling Green State Univ., Bowling Green, OH.

Dambach, C. A., and D. L. Leedy. 1948. Ohio studies with repellent materials with notes on damage to corn by pheasants and other wildlife. J. Wildl. Manage. 12: 392-398.

DeGroot, P. 1980. Information transfer in a socially roosting weaver bird (*Quelea quelea*; Ploceinae): an experimental study. Anim. Behav. 28: 1249-1254.

DeHaven, R. W., D. F. Mott, J. L. Guarino, J. F. Besser, C. E. Knittle, and E. W. Schafer, Jr. 1979. Methiocarb for repelling birds from ripening sweet cherries. Intnl. Pest Cont. 21: 12-14, 21.

Dolbeer, R. A. 1981. Cost-benefit determination of blackbird damage control for cornfields. Wildl. Soc. Bull. 9: 44-51.

Duncan, R. R. 1980. Methiocarb as a bird repellent on ripening grain sorghum. Can. J. Plant Sci. 60: 1129-1133.

Dyer, M. I. 1976. Redwinged blackbird flock feeding behavior in response to repellent stress. Pages 204-224 in W. B. Jackson (editor) proc. 7th bird Control Seminar. Bowling Green State Univ., Bowling Green, OH.

Emlen, S. T., and N. J. Demong. 1975. Adaptive significance of synchronized breeding in a colonial bird: a new hypothesis. Science 188: 1029-1031.

Feare, C. J., D. D. B. Summers, and R. Longstaff. 1978. Toxicity of endrin-treated pear buds to bullfinches. Expl. Hort. 30: 42-45.

Flaherty, D. L., C. D. Lynn, F. L. Jensen, and D. A. Luvisi. 1969. Ecology and integrated control of spider mites in San Joaquin vineyards. Calif. Agric. 23: 11.

Genovese, R. F., and M. P. Browne. 1978. Sickness-induced learning in chicks. Behav. Biol. 24: 68-76.

Green, R. 1980. Food selection by skylarks: the effect of a pesticide on grazing preferences. Pages 180-187 in E. N. Wright (editor) Proc. Conf. Understanding Agricultural Bird Problems. Univ. of London.

Horn, H. S. 1968. The adaptive significance of colonial nesting in the Brewer's blackbird (*Euphagus cyanocephalus*). Ecology 49: 682-694.

Hothem, R. L., D. F. Mott, R. W. DeHaven, and J. L. Guarino. 1981. Mesurol as a bird repellent on wine grapes in Oregon and California. Am. J. Enol. Vitic. 32: 150-154.

Ingram, C. R., R. T. Mitchell, and A. R. Stickley, Jr. 1973. Hopper box treatment of corn seed with methiocarb for protecting sprouts from birds. Pages 206-215 in W. B. Jackson (editor) Proc. 6th Bird Control Seminar. Bowling Green State Univ., Bowling Green, OH.

Joyner, D. E., J. D. Somers, F. F. Gilbert, and R. J. Brooks. 1980. Use of methiocarb as a blackbird repellent in field corn. J. Wildl. Manage. 44: 672-676.

Krebs, J. R. 1974. Colonial nesting and social feeding as strategies for exploiting food resources in the great blue heron (*Ardea herodias*). Behaviour 51: 99-131.

Logue, A. W. 1980. Visual cues for illness-induced aversions in the pigeon. Behav. Neur. Biol. 28: 372-377.

Luckwill, L. C., and P. S. Weaver. 1964. Techniques for the study of bird repellents. Annual Report of the Agricultural and Horticultural Research Station, Long Ashton, Bristol. p. 64-72.

Mann, F. M., Jr., H. J. Derr, and B. Meanley. 1956. Bird repellents for direct seeding longleaf pine. Forests and People 6: 16-17, 48.

Mason, J. R., J. F. Glahn, R. A. Dolbeer, and R. F. Reidinger. 1985. Field evaluation of dimethyl anthranilate as a bird repellent livestock feed additive. J. Wildl. Manage. 49: 636-642.

__________, and R. F. Reidinger. 1982. Observational learning and food aversions in red-winged blackbirds (*Agelaius phoeniceus*). Auk 99: 548-554.

______________________________. 1983a. Importance of color for methiocarb-induced food aversions in red-winged blackbirds. J. Wildl. Manage. 47: 383-393.

______________________________. 1983b. Generalization of and effects of pre-exposure on color-avoidance learning by red-winged blackbirds (*Agelaius phoeniceus*). Auk 100: 461-468.

Mason, J. R., A. H. Arzt, and R. F. Reidinger. 1984. Comparative assessment of food preferences and aversions acquired by blackbirds via observational learning. Auk 101: 796-803.

Moulton, D. W. 1979. Evaluation of methiocarb for repelling blackbirds from cultivated wild rice. J. Wildl. Manage. 43: 747-751.

Neff, J. A., and B. Meanley. 1956. A review of studies on bird repellents. Prog. Rpt. No. 1 - Research on bird repellents. U. S. Fish and Wildlife Service, Denver Wildlife Research Center. 13 pp.

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. Pages 150-165 in R. W. Bullard (editor) A.C.S. Symposium Series No. 67, Flavor Chemistry of Animal Foods.

______________, and J. T. Linehan. 1977. Some aspects of grackle feeding behavior in newly planted corn. J. Wildl. Manage. 41: 444-447.

Rooke, I. J. 1983. Conditioned aversions by silvereyes *Zosterops lateralis* to food treated with methiocarb. Bird Behav. 4: 86-89.

Rothschild, M., and B. Ford. 1968. Warning signals from a starling *Sturnus vulgaris* observing a bird rejecting unpalatable prey. Ibis. 110: 104-105.

Schafer, E. W., Jr., and R. B. Brunton. 1971. Chemicals as bird repellents: two promising agents. J. Wildl. Manage. 35: 569-572.

Schemnitz, S. D., A. A. Ismail, and F. J. Gramlich. 1976. Effectiveness of methiocarb for repelling birds in Central Maine lowbush blueberry fields. Res. Life Sci. 23(12), 6 p. Maine Life Sciences and Agricultural Experimental Station.

Shumake, S. A., S. E. Gaddis, and E. W. Schafer, Jr. 1977. Behavioral response of quelea to methiocarb (Mesurol). Pages 250-254 in W. B. Jackson (editor) Proc. 7th Bird Control Seminar. Bowling Green State Univ., Bowling Green, OH.

Somers, J. D., F. F. Gilbert, R. J. Brooks, and D. E. Joyner. 1983. Chemical control of depredating blackbirds in Ontario field corn. Pages 225-232 in W. B. Jackson (editor) Proc. 9th Bird Control Seminar. Bowling Green State Univ., Bowling Green, OH.

Stickley, A. R., Jr., and C. R. Ingram. 1973. Two tests of the avian repellent, methiocarb, in Michigan sweet cherry orchards. Pages 41-46 in W. B. Jackson (editor) Proc. 6th Bird Control Seminar. Bowling Green State Univ., Bowling Green, OH.

Stone, R. J. 1976. Chemical repellents can save crops. World Crops 28: 132-133.

Tobin, M. E. 1985a. Cues used by house finches for detecting methiocarb-treated grapes. Crop Prot. 4: 111-119.

__________. 1985b. Cues used by European starlings for detecting methiocarb-treated grapes. J. Wildl. Manage. 49: (1102-1108).

__________, and R. W. Dehaven. 1984. Repellency of methiocarb-treated grapes to three species of birds. Agric. Ecosyst. Environ. 11: 291-297.

Ward, P., and A. Zahavi. 1973. The importance of certain assemblages of birds as "informational-centers" for food-finding. Ibis. 115: 517-534.

West, R. R., R. B. Brunton, and D. J. Cunningham. 1969. Repelling pheasants from sprouting corn with a carbamate insecticide. J. Wildl. Manage. 33: 216-219.

Wilcoxin, H. C., W. B. Dragoin, and P. A. Kral. 1971. Illness-induced aversions in rat and quail: relative salience of visual and gustatory cues. Science 171: 826-828.

Wright, E. N. 1962. Experiments with anthraquinone and thiram to protect germinating maize against damage by birds. Ann. Epiphyties 13: 27-31.