ANIMAL REPELLENTS DERIVED FROM PLANT SPECIES

(Report To The Michigan Cherry Research Committee
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Abstract:
Research to develop an effective repellent for animals has been conducted under natural conditions at East Lansing, Baldwin, the Rose Lake Wildlife Center and on growers farms in NW Michigan and Alpena County. Since the inception of this project in 1996, more than 450 feeding studies with 9,000 field plots have been conducted utilizing plant extracts and commercial repellents. Effective repellents have been extracted from daffodil, iris, catnip, peppermint, spearmint and pepper. Combinations of these were more effective than the individual extracts used at higher rates. The addition of certain wetting agents and emulsifiers has also enhanced repellent activity. The phytotoxicity of daffodil extracts has required its elimination from formulations used on growing plants. The formulations developed in this research are more effective than the commercial products tested. However, further research is required to enhance the longevity of the formulations and to improve handling properties while reducing the cost of the product to the grower.

Introduction:
A practical formulation of an animal repellent, particularly for deer and rabbits would solve one of the most expensive, vexing and annoying problems that affect Michigan farmers, environmentalists and citizens; that is, the damage caused by animals feeding on crop and ornamental species (2,3,8,9,11,12). The objective of this research is to discover animal repellents that occur in native or domestic plant species; and to combine these in a formulation that repels animals, is easily applied, not phytotoxic, resists erosion and breakdown and is sufficiently inexpensive to be used on large acreages.

Another goal is to develop an efficient method for extraction, purification and identification of compounds present in plant species that prevent animals from consuming them. This calls for improved protocols for testing these compounds with wild animals, particularly deer and rabbits.

Literature Review:
The browsing of animals, particularly deer and rabbits, on agricultural and ornamental crops has become an increasingly important problem (4,6,16,17). Considerable research has been conducted to find effective animal repellents resulting in the testing and marketing of natural and synthetic products (Table 1) (5,7,10,13,14,15). This research can be summarized from the literature cited as follows: All of the products have repellent activity of varying degrees, particularly denatonium benzoate (1,21), putrescent whole egg solids and a mixture of mustard oil and capsaicin (1,14,15). Other repellents have been derived from various natural products (5,10,13,19,20).

The formulations available (Table 1) may optimally deter animals for a few weeks but not for a season (4,5,6,7,8,10,15). This is also dependent upon feeding pressure. In addition, the formulations available to the public cost more than ten dollars per quart as applied (2). This makes the currently available repellents economically prohibitive for application to large areas.

Table 1.

Product	Active ingredients	Source
Hot Pepper Wax	capsaicin and other caosaicinoids 0.00018%	Hot Pepper Wax, Inc. 305 Third St Greenville, PA 16125
Tree Guard	Benzyldiethyl ammoniom 0.2% (aka Denatonium Benzoate or Bitrex)	Nortech Forest Technologies, Inc Calvin Blanchard
Deer-Off	Putrescent Whole egg solids 0.78% Capsaicin 0.0006% Garlic 0.0006%	Deer-Off, Inc 1492 High Ridge Rd Stamford, CT 06903-4124
Deer Away (old)	Ally Isothiocynate 0.22% (oil of mustard) Capsaicin and related 0.625% (oleoresin of capsicum) Vegetable oil, lemon extract 99%	IntAgra, Inc 8500 Pillsbury Ave S Minneapolis, MN 55420
Deer Away (original)	Putrescent whole egg solids 4.63%	
Deer Away Powder	Putrescent whole egg solids 36%	
Hot Sauce	Capsaicin 2.5% (oleoresin of capsicum)	Miller Chemical and Fertilizer Corp Hanover, PA 17331
Foggy Mountain Coyote Urine	Coyote Urine 100%	J&C Marketing, Inc PO Box 125 Hampden, ME 04444
XP-20	Thiram 10%	Easy Gardener, Inc. PO Box 21025 Waco, TX 76702
Bobbex	Garlic oil .00048%, dried blood .0024%	Bobbex, Inc. 52 Hattertown Rd Newtown, CT 06407
Hinder	Ammonium soaps of higher fatty acids 13.8%	Pace International Seattle, WA 98104
Ro-Pel	bebzyidiethyl ammonium saccharide .065% Thymol .035%	Burlington Scientific Corp. 222 Sherwood Ave. Farmingdale, NY 11735

After reviewing the literature, the obvious challenge is to discover a compound or mixture of compounds and additives that may be formulated to give an economical product that will remain effective for long periods, even with environmental stresses.

Materials and Methods:

Animals are repelled from eating some plant species. Extracts repellent to animals have been isolated from daffodils, iris, catnip, peppermint, spearmint and pepper. These extracts were formulated alone or in combination with other extracts for testing. The addition of surfactants, additives and emulsifiers to the formulations have enhanced the stability of the extracts and their ease of application.

Field assays were conducted in selected natural environments including northwestern Michigan orchards, Alpena County in the tuberculosis quarantine area and at Baldwin, where a variance was obtained from the Michigan Department of Natural Resources to operate an automatic feeder. These areas attracted many wild animal species including deer, wild turkeys, raccoons, blue jays and squirrels.

At Baldwin, repellent treatments were applied to corn seeds. Seven to 10 treatments of 10 seeds each were placed on plastic trays arranged randomly among the scattered feed and replicated three times. The feeder was turned off during each test to prevent contamination of the treatment trays. The percent corn consumed from the trays was recorded. In general, the repellents isolated have been effective with most animal species. For example, extracts that repel deer also repel squirrels. An advantage of this bioassay procedure with corn seed is that it requires very small quantities of the test compounds. This is important when screening chemicals separated by vacuum liquid or thin layer chromatography where fractions obtained are in very small quantities.

Deer isolated in pens at the DNR Rose Lake Wildlife Center near East Lansing were used for a majority of the 1999 studies. Ears of field corn and boughs of white cedar (*Thuja occidentalis*) 10-20 cm long and 7-12 cm wide, which are desired by deer, were treated with the formulations. The boughs and corn were tied to the inside of a fence enclosing 2-7 deer. Each test contained up to 10 treatments arranged in three randomized complete blocks. The percent consumed by the deer of each cedar bough or ear of corn was recorded.

Tests with rabbits were conducted throughout the year using pansy plants grown in pots or transplanted in beds. Pansies remain desirable to rabbits throughout Michigan winters. In the winter, the plants in pots were hardened off in growth chambers and treated with formulations containing the active fractions. They were moved outside to gardens with a high population of rabbits. These tests were evaluated by estimating the feeding activity on the plants. The results were similar to those shown in Table 2.

Results and Discussion:

Extracts from different plant species were more effective than the commercial preparations in these tests (Table 2). Daffodil leaves and bulbs contain one or more active repellents (Table 3). One of the major problems with daffodil extracts is that they are phytotoxic compared to other plant extracts (Tables 4 and 5). Extracts from iris, pepper, peppermint, spearmint and catnip also have repellent activity (Tables 6 and 7). It is possible to enhance the repellent activity of plant extracts with additives such as vegetable oils (Table 6). The residual repellent activity of plant extracts can be enhanced by the use of surfactants and clay (Table 8). Two new formulations that include clay that

acts as a sticking agent have been encouraging. Under rainy and snowy conditions and heavy animal pressure, the best MSU formulation "Go Green" at 100% remained active for more than 8 days (Table 9).

Conclusions:

Tests with repellents extracted from plants since 1997 have consistently performed better than commercial repellents available.

The results of recent tests with the formulations "Go Green" and "Go White" are particularly encouraging. It is believed that by making changes to improve these formulations that we are finally approaching a tank mixture that may be a first step in helping Michigan growers and homeowners have a useful repellent available.

Significance to the Michigan Industry:

If and when a company can be found that will manufacture and further develop improved formulations of "Go Green" and "Go White"; Michigan growers will have a repellent derived from natural products that can be used year-around, hopefully at a reasonable cost.

Literature Cited:

1. Andelt, W.F. et al. 1994. Effectiveness of capsaicin and bitrex repellents for deterring browsing by captive mule deer. J. Wildl. Mgt. 58: 2, 330-334.
2. Anon. 1998 Consumers Rpt. 63:10.
3. Anon. USDA, National Agricultural Statistics Service, May 26.
4. Bergquist, J. and Orlander, G. 1996. Browsing deterrent and phytotoxic effects of roe deer repellents on Pinus sylvestris and Picea abies seedlings. Scandinavian J. Forest Research. 11: 2, 145-152.
5. Boag, B. and Mlotkiewicz, J.A. 1994. Effect of odor derived from lion feces on behavior of wild rabbits. J. Chem. Ecol. 20: 3, 631-637.
6. Conover, M.R. and Kanis, G.S. 1988. Browsing preference of white-tailed deer for different ornamental species. Wildl. Soc. Bull. 16:175-179.
7. Gartner, S. 1992. The repellent effect of approved deer deterrents. Allgemeine Forst Zeitschrift. 47: 15, 794-795.
8. Kasprowicz, A. 1992. Evaluation of damage by red deer in young silver fir planta tions and the effectiveness of chemical repellents. Sylwan. 136: 11, 19-23.
9. McCallum, M. 1996. MVC asks DNR for better control of deer herd. Great Lakes Vegetable Growers News. Sept.
10. Milunas, M.C. et al. 1994. Effectiveness of odour repellents for protecting ornamen tal shrubs from browsing by white-tailed deer. Crop Protection. 13: 5, 393-397.
11. Nadasy, M. and Takacs, A.. Proceedings: 50th International Symposium on Crop Protection, Gent, Belgium, May 1998, Part II. 63 :2b, 511-518.
12. Nolte, D.L. and Fall, M.W. 1998. Efficacy of selected repellents to deter deer browsing on conifer seedlings. Special Issue: Vertebrate deteriogens. International Biodeterioration and Biodegradation. 42: 2-3, 101-107.

13. Nolte, D.L. et al. 1995. Effectiveness of BGR-P and garlic in inhibiting browsing of western red cedar by black-tailed deer. Tree Planter's Notes. 46: 1, 4-6.
14. Osterberg, M.J. and McAninch 1993. Effectiveness of three commercial deer repellents. MNDNR Wildl. Pop. and Res. Unit. 4pp
15. Schoeb, M.C. and McAninch, J.B. 1996 Efficacy of commercial deer repellents in winter. MNDNR Wildl. Pop. and Res. Unit report. 11pp
16. Sheets, K. 1995. Oh Deer! Fine Gardening Nov/Dec: 54-61.
17. Swezey, L.B. 1997. Outsmarting Bambi. Sunset, Nov: 78-82.
18. Swihart, R.K. et al. 1991. Aversive responses of white-tailed deer, (Odocoileus virginianus), to predator urines. J. Chem. Ecol. 17:4, 767-777.
19. Thivolle-Cazat, A. et al. 1992. Can selenium protect trees from wildlife damage? Informations Foret, Afocel Armef. No. 1, 33-46; Fascicule 428.
20. Wager-Page, S.A. et al. 1997. Variation in avoidance of Siberian pine needle oil by rodent and avian species. J. Wildl. Mgt. 61: 1, 235-241.
21. Wright, I.A. and Milne, J.A. 1996. Aversion of red deer and roe deer to denatonium benzoate in the diet. Forestry Oxford. 69: 1, 1-4.

Table 2. The feeding activity of deer (3 does and 5 fawns) at Rose Lake and deer and squirrels at Baldwin on corn treated with repellent materials. MSU-7 is a formulation of extracts from daffodil, pepper and catnip. Tests started 11/8/99 and 11/14/99 respectively.

	Percent consumed			
	Rose Lake		Baldwin	
Treatments	1 day	2 days	1 day	2 days
Control	100	100	67	100
MSU-7	0**	12**	0**	70*
Deer Away (A)[a]	57*	100	53	100
Deer Away (B)[a]	70	88	43	100
Coyote urine	40*	98	3**	100
Ro-Pel	92	100	100	100
Bobbex	97	100	0**	100
Hinder	100	100	0**	100
Tree GuarD	80	100	23	100
XP-20	100	100	83	100

*,** Significantly different from the control at P≤ .05 and .01 respectively
[a] There are two formulations of Deer Away: "A" contains putrescent whole egg solids and is currently available. Formulation "B" contains mustard oil, capsaicin and lemon extract.

Table 3. A comparison of the repellent activity of extracts from daffodil bulbs and leaves on cedar boughs to deer at Rose Lake and on corn seeds to squirrels at E. Lansing. Test started 3/20/99 and 3/25/99 respectively.

		Percent consumed			
		Deer		Squirrels	
Treatments	mg/ml	11 days	13 days	1 day	3 days
Control	0	67*	100	93	100
Daffodil bulbs	25	23*	57*	3*	80
Daffodil bulbs	100	0*	67*	10*	7**
Daffodil leaves	20	17*	90	83	100
Daffodil leaves	80	53	90	27*	60*

*,** Significantly different from the control at P ≤ .05 and .01 respectively

Table 4. The toxicity of daffodil extracts when applied to apple shoots and 14-day-old corn seedlings. Test started 6/25/99.

			Injury[a]	
Treatments	mg/ml	soybean oil	Apple	Corn
Control			1.0	1.0
Daffodil bulb	20		2.5*	2.0*
Daffodil bulb	40		2.5*	5.0**
Daffodil bulb	80		2.5*	5.0**
Daffodil leaves	5	1.8%	1.0	1.3
Daffodil leaves	10	3.7%	1.0	1.7
Daffodil leaves	20	7.4%	1.0	1.0

*,** Significantly different from the control at P≤.05 and .01 respectively
[a] Rating 1=none; 5=severe

Table 5. The toxicity of different formulations of daffodil extracts when applied to new shoots of apple trees. Test started 6/8/99.

Treatments	Injury[a] ratings after 7 days
Control	1.0
Methanol	1.0
Hexane	3.0*
Surfactants	1.0
Surfactants+Soybean oil	1.5
Daffodil in water	3.0*
Daffodil in methanol	3.5**
Daffodil with surfactants	4.0**

*,** Significantly different from the control at P≤.05 and .01 respectively
[a] Rating 1=none; 5=severe

Table 6. The feeding activity of deer on cedar boughs and squirrels on corn seed treated with repellent materials at Rose Lake and East Lansing respectively. Tests started 2/17/99 and 2/20/99 respectively.

	Percent consumed			
	Deer		Squirrels	
Treatments	1 day	14 days	1 day	4 days
Control	100	100	100	100
Daffodil	0**	67*	0**	0**
Iris	0**	100	100	100
Peppermint oil	7**	100	90	100
Daffodil+Iris	0**	57*	0**	25**
Daffodil+Peppermint oil	0**	70	0**	0**
Iris+Peppermint oil	3**	80	10**	97
Daffodil+Iris+Peppermint oil	0**	67*	0**	3**

*,** Significantly different from the control at P≤ .05 and .01 respectively

Table 7. The feeding activity of 6 deer at Rose Lake on ear corn treated with extracts from pepper and catnip alone and in different combinations. Test started 11/29/99. More than 2 inches of snow and rain fell during the first 5 days.

		Percent consumed			
Treatments	mg/ml	1 day	5 days	9 days	13 days
Control		100	100	100	100
MSU-7	A	0**	0**	3**	22**
Pepper	10	5**	67	100	100
Pepper	30	0**	2**	33*	35**
Catnip	10	33**	70	83	100
Catnip	30	35**	68	100	100
Pepper + catnip	10+10	0**	17**	68	73*
Pepper + catnip	10+30	0**	3**	40*	65*
Pepper + catnip	30+10	0**	2**	35*	67*
Pepper + catnip	30+30	0**	0**	5**	63*

A MSU-7 is a formulation of extracts from daffodil bulbs, catnip and pepper with surfactants.

*,** F value is significantly different from the control at P≤ .05 and .01 respectively

Table 8. The feeding activity of 6 deer at Rose Lake in ear corn treated with repellents formulated with or without Kaolin clay. Test started 12/13/99. More than 1 inch of snow and rain fell during the first 2 days.

		Percent consumed			
Treatments	mg/ml or %	1 day	2 days	4 days	7 days
Control		100	100	100	100
Clay	2%	100	100	100	100
Pepper	30 mg	0**	33*	67	67
MSU-7	A	0**	67	67	67
Pepper + clay	30mg + 2%	0**	0**	0**	20*
MSU-7 + clay	A + 2%	0**	0**	3**	33*

A MSU-7 is a formulation of extracts from daffodil bulbs, catnip and pepper with surfactants.

*,** F value is significantly different from the control at P≤ .05 and .01 respectively

Table 9. The feeding activity of squirrels on two new repellent formulations; "Go Green" which includes extracts from pepper, catnip and peppermint plus a green dye on clay and surfactants. This formulation is not phytotoxic and may be used on growing plants. "Go White" may be toxic to growing plants because it contains daffodil bulb extract which replaces the peppermint extract in the "Go Green" formulation. This formulation would be best for dormant plants or species resistant to the daffodil extract. This test was started on 12/24/99. There was both rain and snow during the period of this test.

		Percent consumed		
Treatments	% of formulation	1 day	3 days	8 days
Control	—	63	63	100
Clay	10	33	67	100
"Go Green"	12.5	17**	17*	93
"Go Green"	25.0	0**	3**	40**
"Go Green"	50.0	0**	0**	3**
"Go Green"	100	0**	0**	0**
"Go White"	12.5	0**	30*	67*
"Go White"	25.0	0**	20*	47*
"Go White"	50.0	3**	3**	13**
"Go White"	100	0**	10*	17**

*,** F value for comparison with control significant at P≤ .05 and .01 respectively