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EFFICACY DATA FOR REGISTRATION OF STRYCHNINE GRAIN BAITS TO CONTROL POCKET GOPHERS (Thomomys spp.)

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ABSTRACT: Laboratory tests, field telemetry trials, and actual use field efficacy evaluations showed that a 0.5% strychnine alkaloid steam-rolled oat-groat hand-bait formulation (EPA Reg. No. 56228-20) with molasses, salt, glycerine, and soda was effective in controlling northern pocket gophers (Thomomys talpoides). Baits retaining at least 0.5% strychnine (w/w) were as effective (>95% control) as baits with 0.75% and 1.0% strychnine in field telemetry hand-baiting trials as well as operational hand-baiting and burrow-builder baiting field tests in forest habitat. Data indicated that the 0.5% strychnine hand bait (molasses formulation) should be reregistered and would be a good substitute for the 0.5% strychnine-Rhoplex bait (EPA Reg. No. 56228-12) currently registered for burrow builder use for pocket gopher control. Both the retention of strychnine on bait, and use of a highly palatable top quality bait carrier were two important factors affecting efficacy of the bait.

Proc. 14th Vertebr. Pest Conf. (L.R. Davis and R.E. Marsh, Eds.)
Published at Univ. of Calif., Davis. 1990.

INTRODUCTION

In 1984, 1986, and 1987, the Environmental Protection Agency (EPA) issued Data Call-in notices requiring the Animal and Plant Health Inspection Service (APHIS) to supply a variety of chemical and toxicological information to support registration of APHIS' 0.5% strychnine hand bait (EPA Reg. No. 56228-20) and 0.5% strychnine burrow builder bait (EPA Reg. No. 56228-12) for control of pocket gophers (Thomomys spp.). Available chemistry data satisfied most of the "Call-In" requirements. However, unpublished toxicity data on file at APHIS' Denver Wildlife Research Center (DWRC) as well as published information on hand baiting of gophers (Barnes 1974, Crouch and Frank 1979, Barnes et al. 1982) and burrow builder baiting of gophers (Barnes et al. 1970, Hegdal and Gatz 1976) did not meet EPA's (1986) laboratory and field efficacy data requirements for these baits.

In 1988, DWRC initiated laboratory and field efficacy studies to retain registration of strychnine grain baits for control of Thomomys and Geomys pocket gophers. This paper presents the results of studies of the strychnine oat-groat molasses bait formulation for control of Thomomys pocket gophers. Tests with the Rhoplex[a] formulation and with Geomys will be reported at a later date.

METHODS AND MATERIALS

Laboratory efficacy studies, field probes, and actual use field efficacy tests were conducted with northern pocket gophers (T. talpoides) as the test species; high quality oat groats (oats without hulls) were used as the bait carrier with APHIS's hand-bait mix (EPA Reg. No. 56228-20) containing strychnine alkaloid, molasses, salt, soda, and glycerin. The northern pocket gopher was selected to represent all species of Thomomys because of its distribution throughout the West (Hall 1981, Teipner et al. 1983) and because of its status as a major pest to the forest industry (Barnes 1973). We chose good, plump, clean Otana (squirrel-type) oats as a carrier because of its extensive and preferred use by the Forest Service to control forest pocket gophers (L. Birch, USFS, pers. comm.). We chose the molasses formulation because of sporadic results with Rhoplex as an adhesive in laboratory tests (Matschke and McCann 1989) and questionable results of a 1989 radio-telemetry field trial (unpubl. data on file, DWRC). Technical grade strychnine alkaloid was used in all formulations; appropriate amounts were added to all concentrations to compensate for impurity and loss of toxicant to mixing equipment.

Laboratory Tests

Laboratory efficacy tests were conducted at DWRC in early 1988 to determine the approximate lowest strychnine concentration (by weight of total bait) that will cause 100% mortality to northern pocket gophers using methods and materials described by Matschke and Andrews (1989). A series of strychnine concentrations above and below the registered 0.5% concentration were tested in no-choice, 3-day, feeding trials with the strychnine oat-groat molasses mix. A 3-day challenge test with strychnine bait and plain oats also was conducted to assess possible aversion to the bait.

Northern pocket gophers, live trapped in forest rangeland habitat north of Denver, Colorado, and transported to DWRC for testing, were housed individually in stainless steel cages and maintained in accordance with USDA animal care regulations. All animals were acclimated to laboratory conditions for a minimum of 14 days prior to testing and observed twice daily for 7 days posttreatment.

Radio-Telemetry Field Trial

A radio-telemetry field trial was conducted September 11-29, 1988, in south-central Washington to determine efficacy of hand baiting with strychnine alkaloid oat groats (molasses formulation) on northern pocket gophers in coniferous forest habitat. Data from these trials were needed to prescribe concentrations of strychnine for field testing under actual use conditions.

In the trial, we instrumented 66 northern pocket gophers with radios and monitored them for at least 48 hours before bait application. We monitored them by radio tracking and by using the open-hole activity assessment (Richens 1967, Barns et al. 1970). Eight nonradioed gophers were also monitored with open holes; these served as supplemental test

[a]Use of trade names does not constitute U. S. Government endorsement.

animals if additional ones were needed to meet a minimum number of 12 gophers per treatment.

On the day scheduled for baiting, we chose 54 of the most active gophers with radios and 6 of 8 of the most active nonradioed gophers for testing. Of the 12 gophers with radios not selected, 2 (17%) died from unknown causes, 3 (25%) failed to plug holes or show normal movement, and 7 (58%) were killed by predators. Because of possible snowfall that would have cancelled the trial, we did not attempt to live trap and radio instrument additional animals for testing. Rather, we chose 6 gophers with radios and 6 gophers without radios for the 0.0% control bait, believing that these animals constituted a suitable control group.

For the trial, experimental strychnine bait concentrations derived from laboratory tests at DWRC with target concentrations of 0.75%, 1.1%, and 1.25%, were tested against the standard 0.5% bait and a 0.0% control bait. Each concentration was directed at five groups of 12 widely separated test gophers per group. Bait was applied by spoon in burrows located in circular 0.027-ha (1/15 A) test units. Burrows were closed and marked after bait was in place. Rate of application was approximately 0.75 kg/ha (0.67 lbs/A). Dead animals were excavated starting 3 days after baiting. Surviving animals were live trapped or kill trapped 7 days after baiting. All recovered animals were shipped frozen to DWRC for strychnine analysis. Habitat type, test design, instrumentation, telemetry equipment, monitoring, recovery location of test animals, and recovery methods used in the trial are described in detail by Evans and Campbell (1989).

Field Efficacy Tests

"Actual-use" hand-baiting and burrow builder-baiting tests were conducted in 1989 on the Ashton Ranger District of the Targhee National Forest in eastern Idaho to determine the lowest concentration of strychnine on grain that would effectively control *Thomomys* pocket gophers. Bait concentrations that were tested were 1.0%, 0.75%, 0.5%, and 0.0% active strychnine (by weight of total bait). Separate batches of bait (one for application by hand, the other for application by burrow builder) were mixed by the Pocatello (Idaho) Supply Depot using technical grade strychnine alkaloid, molasses, soda, salt, starch, glycerin and steam-rolled oat groats. Bait samples for strychnine analysis were taken immediately after mixing, from sacks immediately before application, and from baiting equipment (bait jugs and burrow builder hopper) immediately after treatment of study units. Application of the experimental baits was done under State of Idaho Experimental Use Permits (EUP-ID-89-01 and EUP-ID-89-02).

Twenty lodgepole pine (*Pinus contorta*) regeneration study units were used to evaluate the hand bait; another 20 study units were used to evaluate the burrow builder bait. The units ranged from 3.24 ha (8 A) to over 38.5 ha (95 A) in size with habitat similar to that described by Barnes et al. (1985). Exact locations, site conditions, and timber management schemes are described by Evans et al. (1990a,b).

Each hand-baiting study unit contained 30 circular gopher activity sampling plots to assess efficacy. Each burrow builder study unit contained 25 sampling plots. The size of each sample plot was 0.027 ha (1/15 A) with a 9.3-m (30.4-ft) radius. The plots were at least 20 m (65.6 ft) apart.

The open-hole procedure (Richens 1967, Barnes et al. 1970) and the plot- occupancy, mound-building census method (Anthony and Barnes 1983) were used in each sample plot to determine if it was active or not. In the open-hole procedure, we flagged two gopher mounds in each sample plot before bait application (hand-bait evaluation) or immediately after application (burrow builder treatment). Afterwards, we periodically opened burrows near each flag and examined them 48 hr later to see if either burrow had been plugged. Plugged burrows indicated presence of a live gopher(s), unplugged burrows indicated that the gopher(s) within the sample plot had been poisoned. Concurrent with open-hole censusing, we leveled all gopher sign inside a circular 81 m^2 (1/50 A) plot occupancy (PO) subplot and examined it 48 hrs later. Fresh gopher sign in the subplot indicated that the plot was active. Thus, we used two independent measures of activity within each sample plot.

Baiting was done operationally by private applicators under contract with the Targhee National Forest using bait application procedures described by Birch (1986). Hand baiters were contracted to treat entire clearcuts plus a buffer strip around each clearcut, to place 1 teaspoonful of bait (about 4 g; 0.14 oz) in an active burrow through a probe hole, cover and mark the hole, and bait up to seven sets per 0.027 ha (1/15 A). Burrow builder operators were required to treat entire clearcuts and some buffer areas but not adjacent areas containing newly planted trees.

Hand-bait study units were initially baited June 30 - July 1, but had to be retreated July 8 - 1 1 because of poorly placed bait sets, insufficient amount of bait, and inadequate coverage. The total rate of application was approximately 0.56 - 1.12 kg/ha (1/2 - 1 lb/A).

Burrow builder treatment was done between August 20 and September 1 with a D-2 bulldozer and a forest land burrow builder similar to the one described by Cannutt (1969). With the burrow builder, entire study units and some adjacent treeless buffer zones were baited with bait dropped about every 0.9 m (3 ft) in artificial burrows spaced about 4.5 - 7.6 m (15 - 25 ft) apart. Burrow builder study units did not have to be rebaited. The rate of treatment was 1,68 - 2.24 kg/ha (1-1/2 - 2 lbs/A).

Entire study units were systematically searched for animal carcasses 1 and 2 days after they were baited. In addition, sample plots were thoroughly searched at the start and end of each 48 hr activity survey. Usable carcasses were numbered, wrapped in foil and plastic, identified, placed on ice, and subsequently frozen; these were later sent to DWRC for strychnine analysis. Carcasses that were putrefied or partially destroyed by carrion-eating insects were removed from the study units and deeply buried.

Efficacy of the bait was assessed as the percent of sample plots that became inactive over time. This is also expressed as % control.

RESULTS

Laboratory Tests

Results of laboratory efficacy studies are presented in Table 1. Ten animals each were used in treatments and 20 animals were used as controls. The 0.75%, 1.1%, and 1.25% concentrations killed 100% of the test animals; the 0.6% and 0.5% baits killed 80% and 90% of the animals, respectively; and the 0.35% and 0.2% concentrations killed 50% and 30% of the animals, respectively. In supplemental findings (not shown in Table 1), a 1.6% strychnine bait concentration killed 100% (5/5) of the animals in a preliminary test. In the 3-day challenge test with untreated, thick, steam-rolled oats as the challenge bait, 100% (20/20) of the test animals died from

consuming 1.0% strychnine treated bait indicating no obvious aversion to the bait. No control gophers died in either test.

Table 1. Results of 3-day, no-choice, laboratory range-finding efficacy tests of strychnine alkaloid treated steam-rolled, oat groats (molasses formulation) presented ad libitum to northern pocket gophers (Thomomys talpoides) in 1988.

% Strychnine in bait						
Target concentration formulation	Analyzed concentration Mean	Analyzed concentration S.E.	No. gophers treated	Mean bait consumption[a] (g)	Gophers killed Number	Gophers killed %
0.00	0.00	0.00	20	6.46 a	0	0
0.20	0.21	0.01	10	3.77 b	3	30
0.35	0.39	0.02	10	1.80 bc	5	50
0.50	0.54	0.02	10	1.40 cd	9	90
0.60	0.66	0.003	10	0.62 d	8	80
0.75	0.81	0.01	10	0.58 d	10	100
1.10	0.94	0.02	10	0.69 d	10	100
1.25	1.27	0.02	10	0.30 d	10	100

[a]Means with no letter in common are significantly different at an error rate of .05 (Duncan's multiple range test).

Bait consumption by animals killed on Day 1 ranged from 0.03 g for the 1.6% bait to 5.81 g for the 0.5% bait. Strychnine intake ranged from less than 0.5 mg/kg in 1.6% bait-killed gophers to 378 mg/kg in 0.5% bait-killed gophers. Basically, bait and mg/kg intake of strychnine alkaloid was considerably less at the higher concentrations than at the lower concentrations.

Radio-telemetry Field Trial

Results of the trial and strychnine residue assay of pocket gopher tissues are presented in Table 2. Chemical analysis of baits indicated that all were within 10% of the target strychnine concentrations. All 12 control gophers survived, but only one of the strychnine baited gophers (baited with the standard 0.5% bait) survived treatment. The 13 test survivors and 5 nontest gophers were live trapped or kill trapped to conclude the test 7 days after bait application.

Of the 47 gophers that died from strychnine bait, 46 died within 36 hr after baiting and one died 3 days after baiting. Only one of the 47 dead gophers--a 0.5% kill--was found above ground near an open bait site. Of the 46 recovered below ground, 18 (36%) were found in nests at a mean depth of 69.3 cm (27.3 in); the remaining 28 (61%) were found in burrows at a mean depth of 45.0 cm (17.7 in).

The only evidence of nontarget mortality associated with the strychnine bait was the recovery of 5 deer mice (Peromyscus maniculatus) above ground near open bait sites. All of the deer mice were recovered in the block treated with the 1.25% strychnine bait.

Field Efficacy

Hand-baiting evaluation.--Plot activity analysis disclosed no differences among the 0.5%, 0.75%, and 1.0% strychnine baits applied by hand; all were shown to be 96% - 97% effective 46-51 days after application (Table 3). The

Table 2. Efficacy of molasses formulation of strychnine alkaloid treated oat-groat baits (EPA Reg. No. 56228-20) in controlling free-roaming, radio-instrumented, northern pocket gophers (Thomomys talpoides) on forest land in south-central Washington, September 1988.

Target strychnine formulation (%)	Assayed strychnine in baits (%)	Gophers killed/ number tested	Strychnine residue (ppm) in tissue[a] Median	$\bar{x}$	SD	Range
0.00	0.00	0/12	--	--	--	--
0.50	0.54	11/12	10.54	10.28	5.20	1.05 - 20.00
0.75	0.79	12/12	9.68	12.05	5.72	4.08 - 23.00
1.10	1.17	12/12	6.00	7.46	5.71	0.20 - 19.00
1.25	1.27	12/12	12.50	19.14	23.45	1.98 - 90.00

[a]Pocket gopher carcasses with skin, head, and feet removed. The limit of detection was 0.085 ppm strychnine; residue detected for the 0.00% formulation was less than this limit. The observed value of 90 ppm was above the upper validation limit. Recovery of strychnine from control tissues fortified with strychnine at the 5 ppm level was 88.0% (SD 7.9%).

analyzed strychnine concentration on freshly mixed bait and on bait immediately prior to placement under ground did not differ appreciably from the formulated concentration indicating very little or no loss of strychnine from bait.

Burrow builder evaluation.--There was a significant difference in observed gopher activity in burrow builder test units treated with the 0.5% strychnine bait compared to test units treated with 0.75% and 1.0% formulations. The 0.5% treatment showed a mean control of 85% compared to 98% for the 0.75% and 1.0% treatments (Table 3). Two of five of the 0.5% test units showed only 76% control effectiveness and the remaining three showed 82%, 92%, and 100% control. The low kill may have been because the bait applied to the units was less than the target of 0.5%. Most of the other units showed a 96% - 100% control effectiveness with baits exceeding 0.5% at time of application.

There was an obvious disparity between the strychnine content of the 0.5% burrow builder bait and the 0.5% hand bait (Table 3), even though both batches of bait were formulated in the same way with the same ingredients. The difference was quite likely due to a substantial loss of strychnine between time of mixing and time of application with the burrow builder. Causes of the strychnine loss from the burrow builder bait and not from the hand bait are unknown.

Carcass recovery.--We found 13 gopher carcasses above ground in the hand baiting evaluation and 2 gophers above ground in the burrow builder evaluation; none were in the 0.5% study units. Three other gophers were found in burrows that were opened for open-hole censusing; 2 of these were in 0.5% study units. Only 4 gopher carcasses were saved for assay; the others were not saved because they were either too putrefied or too mutilated by insects.

The only evidence we found of nontarget mortality was associated with the hand-baiting field assessments where we found 5 western jumping mice (Zapus princeps) and 2 deer mice. All jumping mice were found above ground in units treated with the 0.75% strychnine bait. One deer mouse was found in a 1.0% treatment unit, the other in a 0.75% treatment unit. Only one jumping mouse was saved for tissue residue analysis. The remaining nontargets were too putrefied or mutilated to save.

CONCLUSIONS

Our data showed that APHIS' 0.5% strychnine alkaloid, molasses, steam-rolled oat-groat bait formulation (EPA Reg. No. 56228-20) applied by hand or by burrow builder will effectively control Thomomys pocket gophers in forest habitats. Because of the diversity of vegetative cover of study units in our evaluation, we see no reason why the 0.5% strychnine oat bait will not produce good results in other noncrop areas where Thomomys are a problem.

We attribute the differences in bait efficacy between the 0.5% hand-applied-bait and the burrow builder-applied-bait to an insufficiency of strychnine on the burrow builder bait. We do not know why strychnine bait used in the burrow builder tests assayed at a lower concentration at time of application than when it was mixed. We believe the loss of the strychnine from the bait used in the burrow builder may be caused by the molasses/salt/starch formulation. The additions of salt and starch in the molasses formulation need to be reevaluated.

Use of the molasses/oat-groat/salt formulation in bait for the burrow builder presented some minor flow-through problems, mainly during rainy days. The greatest problem was caking of salt, starch, and other fines in the feeder mechanism. Covering the bait hopper with a plastic bag and periodically loosening the fines from the feeder mechanism alleviated this problem. A salt-free bait would also alleviate the "caking" problem.

Table 3. Summary of formulated and analyzed concentrations of strychnine oat-groat baits (molasses formulation) and control of northern pocket gophers (Thomomys talpoides) in actual use hand baiting and burrow builder baiting tests on the Targhee National Forest in eastern Idaho in 1989.

Application method	Formulated conc. (%)	Analyzed concentration (%)		% Control sample plots that became inactive
		Freshly mixed	Prior to placement in ground	
Hand baiting	0.00	0.00	0.00	1 (1/150)
	0.50[a]	0.50	0.50	97 (145/150)
	0.75	0.71	0.71	97 (146/150)
	1.00	1.04	1.10	96 (144/150)
Burrow builder	0.00	0.00	0.00	0 (0/125)
	0.50[a]	0.46	0.39	85 (106/125)
	0.75	0.78	0.53	98 (122/125)
	1.00	0.96	0.83	98 (123/125)

[a]Registered concentration

We also obtained evidence that the burrow builder was very effective in soil conditions that appeared less than ideal for burrow builder use. On August 18, 1989, we treated a 4.1-ha (10-A) unit with 0.75% strychnine bait but did not use the unit in our evaluation believing that soil moisture conditions were too dry for good burrow builder treatment and control of gophers. Numerous excavations of artificial burrows revealed poorly formed tunnels with up to 10 cm (4 in) of loose soil over the bait. Supplemental activity readings in the unit, however, showed 100% control of gophers (25 of 25 sample plots inactive) throughout a 3-week activity assessment period.

In conclusion, we recommend that the 0.5% strychnine, molasses, oat-groat bait formulation (EPA Reg. No. 56228-20) be registered for both hand baiting and burrow builder baiting of Thomomys pocket gophers and that studies be undertaken immediately to improve stability of the strychnine bait for gopher control.

ACKNOWLEDGMENTS

These studies were funded, in part, by the U.S. Forest Service, (FS) National Agricultural Pesticide Impact Assessment Program (NAPIAP). G. Baxter (FS Region 4, Ogden, UT) and H. Black (FS PNW Station, Portland, OR) acted as liaison officers. L. Rolph (Champion International Corporation, WA) and J. Amundson (FS Targhee NF, ID) helped coordinate the field studies. DWRC employees M. Garrison, M. Goodall, and B. Mishalanie helped with bait preparation and chemical analysis. N. P. Groninger made valuable contributions on programming for data analysis. Olympia Field Station employees M. Carey, J. Hageman, and J. Ocheltree aided in the field telemetry trial. APHIS parttime employees W. Bunting, T. Keller, T. Toll, and M. Wolfe provided invaluable assistance in the operational field baiting tests. Special thanks to L. Birch (FS Targhee NF) for facilitating all aspects of the hand baiting and burrow builder portions of the study and for arranging help, transportation, and temporary living quarters for APHIS employees.

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