REDUCED RISK ANTICOAGULANT BAITING STRATEGIES FOR CALIFORNIA GROUND SQUIRRELS

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ABSTRACT: The anticoagulants diphacinone and chlorophacinone (0.01% and 0.005% concentrations) are used extensively for control of California ground squirrels (*Spermophilus beecheyi*). Because of concerns of risks to nontarget wildlife, there is a need to develop baiting strategies that minimize the amount of bait applied, while still providing a high level of control. In 1997 and 1998, we conducted laboratory studies to determine the effect of timing and number of bait applications, and amount of bait given per application on the efficacy of 0.01% diphacinone for California ground squirrels. Results suggest that only two applications with 4 or 5 d between applications are necessary to achieve control. This is in contrast to the label recommendation of three to four applications with 48 h between applications (spot baiting), and two applications with 2 or 3 d between them (mechanical broadcast baiting). Furthermore, in our study, squirrels only required a small amount (less than 4 g of bait) per application to receive a lethal dose. Field studies are underway to test this baiting strategy and various bait application methods in the field.

KEY WORDS: anticoagulant rodenticides, California ground squirrel, diphacinone, nontarget poisoning, secondary poisoning, *Spermophilus beecheyi*

Proc. 19th Vertebr. Pest Conf. (T.P. Salmon & A.C. Crabb, Eds.) Published at Univ. of Calif., Davis. 2000.

INTRODUCTION

The California ground squirrel (*Spermophilus beecheyi*) is a serious agricultural and rangeland pest in California, causing damage estimated at $30 to $50 million annually (Marsh 1994). This species competes with livestock for forage, degrades rangeland, and damages tree, field, and row crops. Squirrels feed on almonds, pistachios, walnuts, apples, apricots, peaches, prunes, oranges, tomatoes, and alfalfa. Vegetables and field crops such as sugar beets, beans, and peas are taken at the seedling stage. Squirrels damage orchard trees by gnawing on the bark. Ground squirrels also are implicated in the transmission of certain diseases, notably plague, to humans.

Ground squirrels are extremely adaptable so indirect control through habitat modification, exclusion, or use of chemical or visual repellents has limited, if any, benefit in most situations. Consequently, poison baits, fumigants, and trapping represent the three major options for control of California ground squirrels (Marsh 1994). Rodenticide-treated baits are the most economical of all approaches to squirrel population reduction and have traditionally been the mainstay of ground squirrel control. The acute rodenticide zinc phosphide, and the anticoagulants diphacinone and chlorophacinone are currently registered for use against this species in California. Of these, the anticoagulants are most frequently used because of their general safety and their low potential to cause bait shyness that is commonly observed with zinc phosphide.

A limitation of anticoagulants is their potential to affect non-target animal species (Hedgal and Blaskiewicz 1984). Because death is delayed for several days following ingestion of a lethal dose, an animal may consume several lethal doses of toxicant. Poisoned rodents also are likely to be available to predators for longer periods because of the delayed time to death. Determining the level of non-target risk is extremely difficult because of the numerous factors involved (Record and Marsh 1988). Laboratory studies have attempted to quantify the risk for several anticoagulants. Evans and Ward (1967) found that mink (*Mustela vison*) and dogs (*Canis familiaris*) died after feeding on nutria (*Myocastor coypus*) killed by anticoagulants (oxycoumarin, diphacinone, pindone, warfarin). Savarie et al. (1979) observed poisoning of golden eagles (*Aquila chrysaetos*) fed muscle tissue from sheep (*Ovis aries*) that had been killed with a single dose of diphacinone. Mendenhall and Pank (1980) observed mortality of barn owls (*Tyto alba*) and great horned owls (*Bubo virginianus*) fed rats [black rats (Rattus rattus); and Polynesian rats (*R. exulans*)] treated with brodifacoum, bromadiolone and diphacinone.

The incidence of non-target species poisoning following California ground squirrel baiting programs has not been well documented. However, there is a need to develop baiting strategies that minimize nontarget risks while still achieving the desired level of control. Our objective was to develop a baiting strategy that reduces the amount of bait applied for control of California ground squirrels. In laboratory tests, we determined the effect of the amount of bait per application, and number and timing of applications of 0.01% bait on control efficacy. We subsequently developed a baiting strategy and are currently testing its effectiveness in the field.

METHODS

We conducted laboratory tests at the University of California, Davis campus, Vertebrate Pest Ecology Laboratory. Methods for testing were approved by the University's Animal Use and Care Administrative Advisory Committee (AUCAAC) (Protocol #7586). Tests were conducted over the periods June to August 1997, and June to July 1998.

We live-trapped California ground squirrels using Tomahawk cage traps baited with oats on the University of California, Davis campus. Squirrels we[re kept] under a 12-h light cycle and constant temperature (between 68 and 76 degrees F) in individual cages in our animal facility. Each squirrel was weighed and provided with water, a cup of steam-rolled oat groats, and a handful of Purina laboratory animal chow. We checked animals daily and replenished food and water as needed. Squirrels were allowed 7 d to acclimate to the laboratory environment.

Treatment Groups

Treatments were defined to test the effect of the amount of bait given per application, and the number and timing of diphacinone bait (0.01% active ingredient) applications on squirrel mortality. For each bait application, we removed all food in the cage and provided squirrels a cup containing a mixture of bait and clean oats. We supplied bait as 10% or 35% of the daily food provision. Our intent was to mimic a field situation where squirrels consume both bait and other foods. The 10% and 35% mixtures were chosen to represent a range of likely bait consumption rates of squirrels in the field.

We initially tested intervals of 2, 5, and 10 d between applications, and one label-recommended treatment (three applications at 2-d intervals) for each application rate. Eight squirrels were randomly assigned to each treatment group. Results indicated that the interval between applications had a much greater effect on mortality than amount eaten per application. We, therefore, only used the 10% bait mixture in additional tests to further evaluate the effect of interval between applications. We increased sample size to 16 squirrels per group and added treatment groups for 3-d and 5-d intervals between bait applications. This resulted in a total of ten different treatment groups for the study (Table 1).

among treatment groups (Table 1). [...] bait given per application did not result in increased mortality, but may have reduced the time until death. Mortality was highest within groups given two applications with a 4- or 5-d interval between them and the group given three applications. The mean time to death was 9.25 d for treatment groups that received applications containing 10% bait at up to 5-d intervals. The mean time to death was 7.0 d for treatment groups that received applications containing 35% bait at up to 5-d intervals.

The mean amount of diphacinone-treated oats consumed from all applications varied significantly among treatment groups [diphacinone-treated oats (g): $F_{9,117}$= 90.95, P <001; mg/kg body weight: $F_{9,117}$=42.19, P <0.001]. As expected, diphacinone consumption was highest for squirrels receiving three bait applications and for those provided with the 35% bait mixture (Table 1).

DISCUSSION

Two concentrations of diphacinone (0.005% and 0.01%) applied on oat groats are currently registered for control of California ground squirrels. The 0.005% concentration may be used in bait stations, while the 0.01% concentration is registered for spot and broadcast applications. The label for mechanically spread 0.01% diphacinone recommends two applications with two to three days between them. For spot baiting, the label recommends providing an uninterrupted supply of bait over a 6- to 8-day period so that all squirrels have the opportunity to find and consume a lethal dose of toxicant. This may involve up to four applications of bait with no longer than 48 h between applications. These

Table 1. Consumption and efficacy of 0.01% diphacinone bait under different baiting strategies in laboratory tests.

				Days to Death			Mean Amount Diphacinone Bait* Producing Death			
Days of Bait Applications	% Bait in Food Provision	% Mortality	*N*	Mean	SE	*N*	g	*SE*	g/kg	*SE*
1, 3, 5	35	75	8	6	0.6	6	36.2	1.6	51.7	3.9
1, 3	35	50	8	4	0.6	4	26.9	2.3	38.8	3.9
1, 6	35	88	8	8	1.2	7	26.0	2.8	33.8	3.6
1, 11	35	50	8	10	3.2	4	22.0	2.2	26.2	0.6
1, 3, 5	10	77	16	9	1.1	18	11.1	0.8	16.9	1.5
1, 3	10	56	16	9	1.8	9	9.4	0.8	11.3	0.8
1, 4	10	56	16	10	2.4	9	8.4	0.6	12.6	0.7
1, 5	10	68	16	9	0.8	19	7.7	0.5	12.2	0.9
1, 6	10	75	20	10	0.9	15	7.1	0.5	11.7	1.3
1, 11	10	46	12	15	2.8	5	6.6	0.7	8.8	0.6

*Diphacinone applied to oat groats (California Dept. of Food and Agriculture registered material).

recommendations are based on the understanding that the effect of anticoagulants on blood clotting time is cumulative, as well as laboratory studies where an unlimited supply of bait has been provided to the target species to determine acceptance of the materials and time until death occurs.

Although diphacinone baiting using the current label is effective in reducing populations of California ground squirrels by more than 84% (Baroch 1996), little is known about the impacts to non-target species. Baroch (1996) reported a nontarget poisoning rate of 0.5 carcasses/ha during a field efficacy test of spot baiting with diphacinone (0.005% and 0.01% concentrations) for California ground squirrel control. This was based on collection of 30 carcasses of eight non-target rodent species and lagomorphs from a 62.5-ha treated area. Squirrel carcasses were collected at the rate of 2.4 per hectare (total of 169 carcasses). No secondary poisoning cases were observed although predators were common in the area, and turkey vultures (*Cathartes aura*) were observed eviscerating squirrel carcasses found on the plots.

Results from our laboratory study suggest that only two applications of bait are needed for control. However, timing of the applications is critical. Two applications with 4 or 5 days between them resulted in high mortality. In contrast, two applications with only 48 h between them (recommended for broadcast baiting), was not effective. Field tests are still needed to determine the effectiveness of two applications at 4-d intervals in the field, and whether it results in fewer cases of nontarget poisonings and lower anticoagulant bait residues in squirrel carcasses (i.e., reduced potential for secondary poisoning).

In addition to timing of bait applications, the application technique used may also influence the potential for non-target poisoning (Record and Marsh 1988) and should be considered. Our study suggests that an individual squirrel needs to consume only a small amount of bait (approximately 4 g) per feeding to obtain a lethal dose. Current baiting techniques probably allow squirrels to consume significantly more bait than needed, thereby resulting in higher anticoagulant residues in carcasses. "Spot" baiting involves hand scattering bait near burrow entrances and provides multiple doses in one location. Bait stations also provide an opportunity for squirrels to consume more than one lethal dose of bait. In contrast, when bait is broadcast mechanically, squirrels have less opportunity to consume excess bait. Baker (1996) demonstrated the influence of baiting technique on chlorophacinone residues in roof rats (*Rattus rattus*). Roof rats exposed to 0.005%-pelleted bait in bait stations were on average 4.3 times higher than residues in rats exposed to a broadcast application. Eighty percent of the carcasses in the broadcast treatments had undetectable residue levels as compared to 20% of the bait station carcasses. Both application methods resulted in greater than 95% control. Our field tests will also focus on bait application techniques to determine those strategies that reduce either the amount or concentration of bait available to squirrels.

ACKNOWLEDGMENTS

This study was funded by the California Department of Food and Agriculture, Vertebrate Pest Control Research Advisory Committee. We thank Brett Wilkins and Eric Figraus for their assistance with the laboratory testing.

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