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Efficacy of Oat and Pellet Anticoagulant Baits Following Treatment with Oat and Pellet Zinc Phosphide Baits: Implications for Secondary Hazard Management

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ABSTRACT: This study was undertaken to demonstrate the efficacy of oat and pellet type anticoagulant baits (0.01% diphacinone) when used following an initial treatment of 2% zinc phosphide oat and pellet type baits for controlling California ground squirrels. Both broadcast oat and pellet anticoagulant treatments following zinc phosphide treatments resulted in apparently good control, although the power of our pellet tests was not strong because of failure in the control plots. Anticoagulant bait use, on a per acre basis, was well below the allowed application rate (10 lbs/acre) because it was applied only where active ground squirrel burrows remained after controlling the entire population with zinc phosphide. No non-target species were found affected by the zinc phosphide or anticoagulant treatments. As a baiting strategy, the combination of zinc phosphide combined with the subsequent selective application of anticoagulant baits was successful. This approach will likely lead to significantly fewer squirrel carcasses with anticoagulant residues, since most are killed with zinc phosphide and subsequently do not pose a significant secondary risk to predators, scavengers, or pets. This baiting strategy has the potential to significantly reduce secondary hazards from ground squirrel baiting.

KEY WORDS: anticoagulants, bait efficacy, bait shyness, California ground squirrels, rodent control, secondary hazards, *Spermophilus beecheyi*, zinc phosphide

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INTRODUCTION

In California, the first-generation anticoagulants diphacinone and chlorophacinone are extremely effective ground squirrel (*Spermophilus beecheyi*) control materials (Salmon et al. 2007). Both of these anticoagulants are commonly used in agricultural and other rural and suburban areas. The extensive use of these materials for ground squirrel control in California, about 1 million lbs of bait per year (Timm et al. 2004), has led to questions about the environmental impact on non-target wildlife since anticoagulants accumulate in the tissues of animals that ingest these baits.

For ground squirrel control using anticoagulants registered by the California Department of Food and Agriculture (CDFA), the active ingredient (a.i.) is mixed with blue dye and oil and is applied to oats at 0.005% or 0.01% a.i. (Clark 1994). Some commercially produced anticoagulant baits are also registered for ground squirrel control. These are generally grain based pellets at the 0.005% or 0.01% a.i. level.

The U.S. Environmental Protection Agency (EPA) recently issued a proposed risk mitigation decision for all rodenticide bait products containing the common anticoagulants including chlorophacinone and diphacinone (US EPA 2008). This decision was based on an evaluation of the ecological risks associated with the use of rodenticide bait products containing 9 anticoagulant active ingredients. The EPA decision will greatly restrict the public use of second-generation anticoagulant bait products containing brodifacoum, bromadiolone, and difethialone. EPA is also requiring labeling changes to mitigate the risks associated with bait products containing any of the 9 anticoagulant rodenticides. The changes would classify diphacinone and chlorophacinone for agricultural uses as Restricted Use Pesticides. This classification will limit their use to certified applicators with sufficient training to know when and how to use them in order to limit risks. The EPA has also proposed eliminating registration of field use 0.01% a.i. anticoagulant bait formulations in both spot and broadcast applications.

While EPA efforts may reduce primary and secondary hazards when using anticoagulant baits, we feel there are additional ways, particularly new baiting strategies, which could also reduce potential risks of these materials to non-target wildlife. Secondary poisoning potential is an important concern for all rodent control programs, but especially where predators, scavengers, and pets are common at the control site. The potential problems are often exacerbated when the population of ground squirrels is high, since the number of carcasses resulting from the control program, especially those found above ground, equates to the secondary poisoning risk. Our past research on ground squirrel control with anticoagulants suggests less that 20% of the poisoned squirrels die above ground (Salmon et al. 2007).

Zinc phosphide is a non-anticoagulant rodenticide for ground squirrel control. It enters the squirrel through ingestion. When the bait contacts the stomach acid, phosphine gas (PH_3) is liberated and rapidly absorbed into the bloodstream. Zinc phosphide baits are formulated for ground squirrel control on oats or pellets, generally at 2.0% a.i. level. Zinc phosphide baits are effective ground squirrel control materials in most but not all cases (Salmon et al. 2000). The lack of control consistency, especially compared with anticoagulant baits, has led to less use of these materials in California. Its Restricted Use Pesticide status likely reduces its use as well. However, a major advantage of zinc phosphide compared to the anticoagulants is the minimal secondary poisoning risk it poses, because the toxicant does not accumulate in the carcass of the target species (Staples et al. 2003). Another advantage is that death occurs rapidly, generally between 15 mins to 4 hrs after exposure.

The major disadvantage of using zinc phosphide bait is its propensity to produce bait shyness if a lethal dose is not consumed. Basically, a squirrel that consumes a sub-lethal dose and becomes sick will associate the sickness with the new (novel) bait. This is most pronounced when the sickness occurs shortly after exposure. If the illness occurs long after exposure, such as the 4-5 day period after initially consuming anticoagulants, the animal does not associate the illness with the new food item. Laboratory tests have shown that the association between illness and a novel taste (like bait) is powerful, can last months, and may transfer to the actual food item (oat or pellet) if that item is itself a new or novel food (Welzl et al. 2001). Because of these types of associations, squirrels may be bait-shy to both the taste of zinc phosphide (it is reported to have a unique taste) and/or to the bait carrier (oat or pellet), since these food items are likely novel in their environment. For this reason, ground squirrel control specialists have recommended against using zinc phosphide more that once annually, and they question whether immediate anticoagulant treatment following zinc phosphide would be efficacious because of possible shyness to the bait carrier, i.e., oat or pellet.

To explore these questions, we conducted field trials to compare the efficacy of oat and pellet anticoagulant bait treatments following treatment with zinc phosphide baits. We used a broadcast baiting strategy for all treatments during this test. Bait types (oats or pellets, zinc phosphide and anticoagulant) were the same at each site. If successful, this baiting regime (zinc phosphide followed by anticoagulant) could lead to significantly reducing secondary hazards of ground squirrel baiting.

MATERIALS AND METHODS

The study was undertaken from 10 May to 11 June 2008. This is the primary time of year when baits are well accepted by squirrels and the adults and young are active above ground (Clark 1994).

Study Area and Site Selection

The study was in rolling hill type oak-woodlands in the Monterey Coastal Range near Parkfield, CA. The area experiences a Mediterranean climate with low rainfall and hot, dry summers. During the study period, maximum temperatures ranged from 81°F to 100°F. Dominant vegetation at all sites was annual grasses and forbs. The area is seasonally grazed by cattle, and some cattle were present during parts of the study. Ground squirrels are common in this area and are considered pests by most ranchers. Our goal was to identify areas with heavy ground squirrel populations, with topography and other features that would make visual observations and broadcast treatment possible.

Ten study sites were identified that met our project objectives. Each had an active population of ground squirrels, had relatively short grass (for easy viewing), was treatable with zinc phosphide and anticoagulant baits, and there were no environmental or public access restrictions. Site size varied from 2 to 24 acres. We mapped these sites using global position system equipment (Garmin eTrex® GPS, Olathe, KS). The perimeter of each site was marked using local landmarks (trees, rocks, and fence lines) and, in some cases, positioning stakes and flags. Once the sites were established, we assessed squirrel presence at each by scanning with binoculars. To do this, we visited each site between 0700 and 1200 hrs and did visual scans to determine if squirrels were present and active. All sites showed heavy squirrel activity and were considered, in our opinion, good candidates for normal ground squirrel control efforts.

Bait Acceptance

Effective ground squirrel control requires that the squirrels eat the bait (Clark 1994). With grain-based baits, the most effective treatment time is late spring and early summer when California ground squirrels switch from eating primarily green, leafy vegetation to eating seeds (Marsh 1998). Since bait acceptance is critical to good squirrel control, we conducted acceptance tests to ensure our bait would be eaten. In the early morning, we piled one teaspoon of untreated oats on bare ground near 5 active burrows within each of the 10 sites. These piles were marked with a flag. In late afternoon, we checked each pile to determine if bait had been removed. We considered a >50% average bait take at all piles as adequate acceptance for baiting to proceed.

Zinc Phosphide Treatment

Each site was randomly assigned to either oat or pellet treatment and then treated with 2% zinc phosphide oats (CDFA, Alameda County, EPA SLN No. 890027) or zinc phosphide pellets (ZP Rodent Bait AG, Bell Laboratories, Madison, WI, EPA No. 12455-17) according to treatment assignment and product label directions. All treatments were broadcast baited using an all-terrain vehicle (ATV) with a Herd® mechanical seed spreader (Herd Seeder Co, Inc., Logansport, IN). The spreader was calibrated prior to the first treatment and periodically re-calibrated during our test, using the methods described in Salmon et al. (2007). Bait was broadcast at a swath width of 43 ft for oats and 22 ft for pellets at the label rate of 6 lbs/acre.

Assessment of Squirrel Presence

Ground squirrel populations were assessed using a method developed uniquely for this study. The approach is based on a visual count index adapted from Fagerstone (1983) with significant modifications. The major difference is that Fagerstone established an activity index based on the number of squirrels sited using a repeat scanning technique over a number of days. Our method did not produce an activity index but rather a presence/absence value reflecting the presence of one or more squirrels in a specific area. The scans were completed between 0700 and 0900 hours when squirrels are most active (Linsdale 1946). Each site was scanned by 2-4 individuals with binoculars. We assessed squirrel presence at specific locations at each site 48 hours after the zinc phosphide treatment. Sighting was accomplished using pairs of observers and binoculars. Once squirrels were sighted, one observer remained at the initial observation point while the second went into the treatment area guided by the first via line-of-sight radio. Each area that had one or more squirrels (usually around a log, rock, tree, or major burrow complex) was identified as a plot and marked using GPS and a stake and flag. After the plots were marked, we scanned the area again to determine, as best we could, that each plot was likely where the squirrel was living (its burrow). In this way, we believe the squirrels would remain in their respective plots over time, since squirrels show considerable fidelity to their burrow system (Boellstorff et al. 1994). Twenty-one days after the initial anticoagulant treatment (see below), each plot was again scanned to determine the presence/absence of squirrels.

Anticoagulant Treatments

All plots at each site were identified on the site map and were assigned to as either a treatment or control plot. We had a total of 22 treatment and 6 control plots at the pellet sites, and 32 treatment and 13 control plots at the oat sites. Our goal was to have about 33% of the plots serve as control but, since total plot numbers varied between sites, the actual number of control plots was slightly less. In our final analysis, 8 control plots were eliminated from analysis because they potentially overlapped with the treatment buffer of another treatment plot.

Forty-eight to 72 hrs after the zinc phosphide treatment, we began treatment with the appropriate anticoagulant bait (oat or pellet mimicking the zinc phosphide treatment at each site). The second anticoagulant treatment was applied 4 days later. The anticoagulant baits were applied at 10 lbs/acre starting at the plot flag and treated continuously in a 75-foot radius. GPS was used to ensure the entire plot area was treated. Control plots were treated with clean oats or non-toxic pellets, as appropriate.

The oat anticoagulant bait was manufactured by CDFA at Alameda County, CA (0.01% diphacinone treated grain, EPA SLN No. 890022). The anticoagulant pellets were manufactured by Bell Laboratories, Madison, WI (P.C.Q. Pelleted Rodent Bait, 0.01% diphacinone EPA SLN CA 780146).

RESULTS

Bait Acceptance

Consumption of the clean oats (5 piles per site) during the one-day bait acceptance trial averaged 67% (Table 1). While one site was below our 50% acceptance goal, we considered the overall acceptance adequate to continue our tests.

Zinc Phosphide Bait Use

Zinc phosphide treated oats or pellets were applied to each of the 10 sites according to label directions. Only active squirrel burrows and other areas where squirrels were present were treated. This treatment simulated an operational control program that a grower might employ. Since bait was only applied to these areas, less than the full 6 lbs/acre was applied at most of the treatment sites (Table 2).

Anticoagulant Bait Use

Pellet and grain type anticoagulants were broadcast on each treatment plot at the rate of 10 lbs/acre (Table 3). Control plots were treated with clean oats or non-toxic pellets as appropriate. Since each plot was treated in a radius of 75 feet from the center stake, the area treated at each plot was approximately 0.4 acres.

Activity Assessment

Twenty-one days following the initial anticoagulant treatment at each plot, the present/absence of squirrels was assessed (Table 4).

Table 1. Acceptance of clean oats bait piles on sites 1-10, Monterey County, CA.

Site	Average % of Oats Eaten
1	40
2	70
3	83.4
4	70
5	49.8
6	48.4
7	60
8	75
9	90
10	80
Overall	66.6

Table 2. Zinc phosphide bait broadcast per study site, near Parkfield, Monterey County, CA.

Site	Acreage	Pounds	June 2008 Pounds / Acre
1	2.65	12	4.52
2	17.51	14	0.80
3	23.36	30	1.28
4	7.22	17	2.35
5	16.97	27	1.59
6	8.25	18	2.18
7	2.31	17	7.36
8	2.59	12	4.63
9	3.1	8	2.58
10	3.12	10	3.20

Table 3. Total anticoagulant bait applied to treatment and control plots, near Parkfield, Monterey County, CA, June 2008.

Site	Treatment*	Acreage	Pounds	
			1st Treatment	2nd Treatment
1	1-AP-B	2.65	6	6
2	1-AO-B	17.51	36	41
3	1-AO-B	23.36	46	57
4	1-AO-B	7.22	20	20
5	1-AO-B	16.97	8	9
6	1-AO-B	8.25	24	25
7	1-AP-B	2.31	13	13
8	1-AO-B	2.59	6	7
9	1-AP-B	3.1	17	17
10	1-AP-B	3.12	4	4

*Treatment: 1 = 0.01% active ingredient, A = Diphacinone, O = Oats, P = Pellets, B = broadcast baited

Table 4. Ground squirrel presence/absence following anticoagulant treatment, near Parkfield, Monterey County, CA.

Treatment Type	Treated Plots	Squirrels Present	
		Yes	No
Pellet	22	3	19
Pellet-Control	3	0	3
Oats	32	6	26
Oat-Control	8	6	2

Baiting Efficacy – Oats

The anticoagulant oat treatments following zinc phosphide oats resulted in good control (no squirrels) at 26 of the 32 treated plots. At the control plots, we expected squirrels to remain after the treatment period and this is exactly what we found; only 2 of the 8 plots had no squirrels present. These differences are significant (Fisher's Exact Test, p = 0.82), although the detection method we used was quite conservative and probably led to less than optimal statistical power.

Baiting Efficacy – Pellets

The anticoagulant pellet treatments following zinc phosphide pellets resulted in good control (no squirrels) at 19 of the 22 treated plots. Data from the control plot were disappointing, since all of the 3 plots showed no sign of squirrels, a possible indication that there was residual effect from the zinc phosphide pellet treatment. The differences between treatment and control plots are not considered significant (Fisher's Exact Test p = 0.67) although they definitely trend toward a positive effect of the anticoagulant pellets. This is likely an artifact of the low number of control plots for this treatment, and the conservative nature of our squirrel assessment. Possible residual effect of the pellets (>48 hours) may have also impacted our results.

Target and Non-Target Species Recovery

Three squirrel carcasses were found during this study, all immediately after the zinc phosphide treatments. These finding are consistent with previous studies where relatively few squirrel carcasses were found above ground (Salmon et al. 2007). Two were on pellet treatment plots (May 21) and one on an oat treatment plot (May 20). Because of the small number of dead squirrels, no inference can be made about potential differences between anticoagulant oat and pellet bait with regard to above-ground kill. No non-target species carcasses (or sick animals) were found during this study.

CONCLUSION AND RECOMMENDATION

This study was undertaken to demonstrate the efficacy of oat and pellet-type anticoagulant baits (0.01% diphacinone) when used following an initial treatment of 2% zinc phosphide oat and pellet-type baits for controlling California ground squirrels. Mechanical broadcast was the application technique for all bait treatments. While pre-baiting for zinc phosphide baits is recommended on the labels of both materials we used, we chose not to pre-bait, since our intent was to target squirrels that survived the zinc phosphide baiting. In theory at least, pre-baiting would have led to fewer squirrels surviving our initial zinc phosphide treatment (Salmon et al. 2000). Both broadcast oat and pellet anticoagulant treatments following zinc phosphide treatments resulted in apparently good control, although the power of our pellet tests was not strong because of failure in the control plots. The application rate for the broadcast method apparently supplied adequate bait to achieve efficacy, and our observations on the plots led us to conclude that minimal excess bait was left in the environment. Anticoagulant bait use, on a per acre basis, was well below the allowed application rate (10 lbs/acre) because it was applied only where active ground squirrel burrows remained after controlling the entire population with zinc phosphide. This led to relatively large areas of the treatment sites being "untreated" with anticoagulants because no squirrels were present. Few dead ground squirrels were found after the zinc phosphide treatment and none after the anticoagulant treatments. No non-target species were found affected by the zinc phosphide or anticoagulant treatments.

As a baiting strategy, the combination of zinc phosphide combined with the subsequent selective application of anticoagulant baits was successful. This approach will likely lead to significantly fewer squirrel carcasses with anticoagulant residues, since most are killed with zinc phosphide and subsequently do not pose a significant secondary risk to predators, scavengers, or pets. This baiting strategy has the potential to significantly reduce secondary hazards from ground squirrel baiting.

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