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THE BAIT SURCHARGE PROGRAM: RESEARCH IMPROVES ZINC PHOSPHIDE USE FOR VOLE CONTROL IN ALFALFA

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ABSTRACT: This paper describes several unexpected benefits of rodenticide-registration research funded by The California Bait Surcharge Program. An enclosure-type study was conducted to determine efficacy of single, pre- and test-bait broadcasts (10 lb./ac.) of 0% and 2% zinc phosphide (Zn_3P_2, CAS #1314-84-7) steam-rolled-oat (SRO) groats to control voles (*Microtus* spp.) in alfalfa (*Medicago sativa*). Unexpected research spinoffs resulted from the use of: 1) eight randomly-located, sieved-dirt plots per enclosure to monitor bait distribution, bait removal, and rodent/avian (non-target) activity; 2) a bait-weathering plot and bait-sample analyses to monitor Zn_3P_2 biodeterioration; and 3) a C++-language program to derive theoretical benefit-cost ratios associated with Zn_3P_2-bait broadcasts.

KEY WORDS: rodenticide, zinc phosphide, field rodents, voles, *Microtus* spp., alfalfa, *Medicago sativa*, benefit-cost, pesticide registration

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INTRODUCTION

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA-88) was amended for the fourth time in 1988 (Federal Insecticide, Fungicide, and Rodenticide Act 1988). Shortly afterwards, the Environmental Protection Agency (EPA) implemented Good Laboratory Practice (GLP) and Quality Assurance (QA) standards (EPA 1989). Together, these events increased the costs associated with registrations of pesticides and decreased the number of registrations/reregistrations maintained or initiated in the U.S. (Sterner and Fagerstone 1997).

By 1990, the California agriculture industry realized the impact of FIFRA-88, GLP, and QA regulations on pesticide registrations; growers/ranchers urged (successfully) the California legislature to pass a bill that required each county agricultural commissioner to collect $0.50/lb. for pest control materials sold, distributed, or used within the state (Vertebrate Pest Control Research Advisory Committee 1994). This "surcharge" provided funds for the registration/reregistration of pesticides. Registration and related research activities would be decided by a Vertebrate Pest Control Research Advisory Committee (VPCRAC), with actual funds/studies monitored by the California Department of Food and Agriculture (CDFA).

In 1992, CDFA initiated a cooperative agreement with the U.S. Department of Agriculture's former Denver Wildlife Research Center (now National Wildlife Research Center). Efficacy and non-target avian hazards studies were needed to register broadcast applications of 2% zinc phosphide (Zn_3P_2) steam-rolled-oat (SRO) groats for vole control (*M. californicus*, *M. montanus*) in alfalfa. Sterner et al. (1994, 1996) reported the results of this efficacy study; whereas, Ramey et al. (1994) and Ramey and Sterner (1995) reported findings of a concurrent study that monitored non-target avian hazards posed by the baits to ring-necked pheasants (*Phaisianus colchicus*) and California quail (*Callipepla californica*). It was shown that successive 10 lb./ac. broadcasts of placebo and lecithin-adhered Zn_3P_2 SRO groats in alfalfa were associated with >94% reduction of introduced voles (Sterner et al. 1994, 1996). Procedures included: 1) an initial 10-day trapout of rodents from 18, 0.5 ac. enclosures; 2) the distribution and acclimation of 428 gray-tailed voles to enclosures (*M. canicaudus*; 23 or 24 voles/0.2 ha enclosure [~125/ha], with genders typically balanced); 3) the distribution of 52 ring-necked pheasants (7 roosters and 45 hens) and 51 California quail (7 roosters and 44 hens) into enclosures; 4) a pre-bait (placebo) broadcast and two-day exposure period; 5) the broadcast of placebo or test baits in nine randomly selected enclosures (3 each designated vole-only, vole-pheasant, and vole-quail, with 8 or 9 birds [≥1 rooster] assigned to respective vole-pheasant and vole-quail enclosures), with a subsequent 14-day exposure period that involved a daily search for vole and non-target carcasses; and 6) a subsequent ≥10-day enumeration (trapout) of the remaining voles.

This paper identifies several research spinoffs that were realized by Sterner et al. (1994, 1996). Methods devised to assess pre-bait effectiveness, bait distribution/pick up, bait biodeterioration, and vole/pheasant/quail activity after Zn_3P_2-bait broadcast have utility to other studies; a theoretical benefit-cost analysis affords insight into the economics of Zn_3P_2 broadcasts for vole control.

RESEARCH BENEFITS

Product Performance Guideline (GDLN) 96-12 (EPA 1982) and CFR 40 (EPA 1996) provide suggested methods/endpoints and GLP procedures needed to satisfy the registration requirements for efficacy determinations of rodenticides. Nevertheless, study directors have latitude to devise/implement novel data collection procedures that will aid evaluations of effects in these studies.

The methods outlined in GDLN 96-12(e) for field efficacy studies and development of a Section 3 (federal) label state that registrants/researchers should: i) submit ≥5 studies for each formulation, site, method of application, major region and species claimed to be controlled by the rodenticide; ii) perform pre- and post-treatment population censuses of rodents (i.e., either direct [capture, mark, release, recapture] and/or indirect [opened or closed mounds/burrows]); iii) use separate control ("placebo") sites; iv) include trials involving different rates, frequencies, and modes of application for baits; and v) conduct studies with environmental factors (e.g., humidity, rainfall, temperature) similar to those expected for future use conditions (EPA 1982). Sterner et al. (1994, 1996) used direct censusing of gray-tailed voles within enclosures under fairly arid conditions (similar to those expected for autumn broadcasts in the Imperial Valley of California), with separate enclosures as control sites. Because VPCRAC envisioned data for a 24c ("special local need") registration to broadcast Zn_3P_2 SRO groats in alfalfa, certain of the aforementioned requirements did not apply (e.g., diverse regional studies, open/closed burrows).

Pre-bait Acceptance Plots and Bait-broadcast Criterion

A key issue facing pesticide applicators and researchers attempting to broadcast Zn_3P_2 concerns the economics/utility of pre-baiting. Although Zn_3P_2 is an effective acute rodenticide for diverse rodents/ applications, bait shyness in sub-lethally-dosed animals has been cited as a negative attribute (Gratz 1973; Marsh 1988; Sterner 1994; Tietjen 1976). Pre-baiting with a placebo bait is commonly believed to mitigate bait shyness. Allegedly, the use of a placebo (pre-bait) affords improved acceptance of a novel grain bait (reduced neophobia) and faster bait ingestion—reduction of sub-lethal toxicosis from Zn_3P_2 hydrolysis and phosphine (PH_3) generation when bait particles are eaten slowly by rodents (Murphy 1986; Sterner 1994).

Sterner et al. (1994, 1996) broadcast a lecithin-coated SRO groat (10 lbs./ac.) as pre-bait. Prior to the broadcast, eight 1 ft^2 sieved-dirt plots were prepared at random locations within each of the 18, 0.5 ac. alfalfa enclosures (Sterner et al. in preparation). Immediately following the pre-bait broadcast, personnel removed all SRO groats that had been broadcast onto these plots, and placed four placebo SRO groats on each plot—1 bait/0.5-ft^2 quadrant (32/enclosure). These plots were then monitored daily for placebo baits (removals) and vole sign. The absence of ≥ 1 ($\geq 25\%$) particle from ≥ 6 ($\geq 75\%$) plots within ≥ 9 ($\geq 50\%$) enclosures was the criterion used to determine sufficiency of placebo acceptance.

The "pre-bait" criterion was exceeded after two days of exposure; 6 and 13 enclosures had ≥ 1 ($\geq 25\%$) particle(s) removed from ≥ 6 ($\geq 75\%$) plots on Days 1 and 2, respectively (Sterner and Ramey in preparation). Although this criterion may be altered, this approach affords an empirical basis for timing the rodenticide broadcast; it also probably contributed to the 94.6% efficacy achieved.

Bait-distribution, Bait-removal, and Vole-/Non-target-avian Activity

The use of sieved-dirt plots within enclosures also helped delineate bait-distribution (density), bait-removal, and vole-/non-target-avian activity subsequent to pre-bait and test-bait broadcasts (Sterner et al. in preparation).

Bait-distribution. Broadcast of 2.5 to 5 crimped oats particles per 1 $ft.^2$ is considered typical for a 10 lb./acre application (T. Salmon, pers. comm. 1993). By immediately counting and removing bait particles from the eight random plots per enclosure, indices of broadcast calibration were obtained. The average ($\pm$SD) SRO groats distributed on plots during pre-bait and test-bait broadcasts (10 lb./ac.) ranged from 2.1 ($\pm$ 2.2) to 5.1 ($\pm$5.5) and from 1.1 ($\pm$1.4) to 6.9 ($\pm$9.1) per enclosure, respectively—confirmation of the adequate calibration of the Spyker® spreaders and applicators.

Bait-removal. In addition to the pre-bait data, cumulative daily counts of Zn_3P_2- and control-SRO groats missing from plots (n = 4/plot and 32/enclosure) served as a useful index of efficacy. All 32 particles were removed from the plots in the control-bait enclosures within 7 to 10 days after broadcast; whereas, 32 particles were removed from only 1 Zn_3P_2-baited enclosure during the 14-day bait-exposure period. These data concur with expected rodenticide effects; reduced vole populations in the Zn_3P_2-bait enclosures offer indirect support for efficacy—low numbers of voles precluded complete bait pick up of these baits.

Vole-/non-target-avian activity. The sieved-dirt plots were scored for the presence:absence (1:0) of vole and avian signs during early morning (~0800-0900 h). Footprint and tail drag sign of voles were distinctive (see Figure 1). Pheasant/quail sign were based largely upon footprints, feathers, droppings, dirt rolls, and soil scratches. Still, discrimination of pheasant and quail sign proved difficult, with footprint size or feather coloration the most reliable features for distinguishing the activity of the species.

Vole activity during the two-day pre-bait period averaged ($\pm$SD) 4.7-4.9 ($\pm$1.8-2.2) plots/enclosure (Sterner et al. in preparation). During the test-bait exposures, vole activity generally declined, but plots in Zn_3P_2-baited enclosures showed more dramatic reductions in activity than placebo-baited enclosures. Mean activity in Zn_3P_2-baited enclosures was 3.1 ($\pm$1.9), 1.2 ($\pm$1.3), and 0.67 ($\pm$0.86) plots for Days 1, 7, and 14 post broadcast, respectively. This compared to vole-activity means ($\pm$SD) of 4.7 ($\pm$1.5), 3.5 ($\pm$2.0), and 2.67 ($\pm$1.9) on Days 1, 7, and 14, respectively, for placebo-baited enclosures. The general decline is somewhat an artifact of precipitation which occurred late in the 14-day exposure period (i.e., 1.01 in. during the last several days) and somewhat obscured dirt plot readings. Nevertheless, the activity patterns again confirmed the efficacy data—lowered activity in Zn_3P_2-baited versus placebo-baited enclosures.

Avian sign on plots in the vole-pheasant and vole-quail enclosures confirmed the locations of the birds. A total of four incidences of avian activity on plots in "vole-only" enclosures were recorded and gallinaceous birds were found to have moved between enclosures on these occasions (Ramey and Sterner 1995).

Regarding activity within each of the six enclosures with pheasants or quail, mean ($\pm$SD) plots with sign during the pre-bait period were 5.4 ($\pm$1.5) and 1.6 ($\pm$1.4), respectively. This disparity between pheasant and quail use of dirt plots appeared valid. The pheasants were observed individually or in groups of two to three birds using the plots as dust rolls and foraging extensively wherever foliage was absent; the quail were observed to

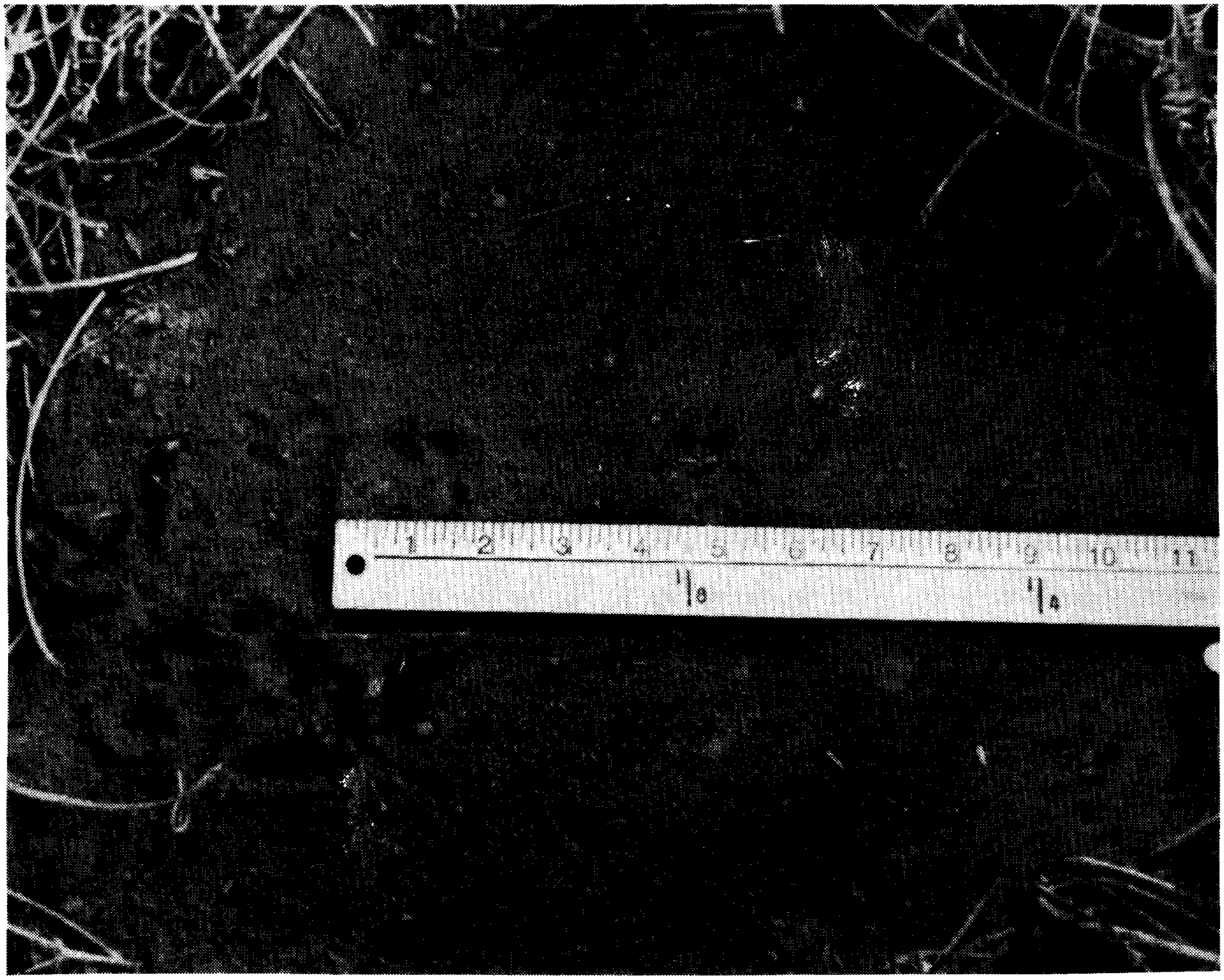

Figure 1. Photograph of a sieved-dirt plot that shows vole (footprints and tail drags) and avian signs (i.e., probable footprints of a ring-necked pheasant).

move as a covey along enclosure edges and less frequently dispersed throughout the foliage. Mean (±SD) avian activity within pheasant enclosures was 4.8 (±1.4), 4.0 (±3.2), and 3.3 (±2.7) for Days 1, 7, and 14 post broadcast, respectively; whereas, mean (±SD) avian activity in quail enclosures was 2.0 (±1.5), 2.3 (±1.4), and 2.5 (±1.4) on these respective days. Serendipidously, on two days, canid (probable coyote, *Canis latrans*) sign was also recorded within plots of avian enclosures.

<u>Bait-biodeterioration Plot and Sample Analyses</u>

Regarding the biodeterioration of Zn_3P_2, CFR 40 (Part 160.105) specifies that:

> (a) The identity, strength, purity, and composition, or other characteristics which will appropriately define the test, control, or reference substance shall be determined for each batch and shall be documented before its use in a study . . . (EPA 1996)

Although the time of this determination is not explicit and is based upon a number of considerations (e.g., stability, storage conditions), at the very least a pre-study analysis of the test material must be performed to demonstrate the a.i. present in a product at or near the time of use.

Sterner and Ramey (1995) published data showing the biodegradation of Zn_3P_2-SRO groats in alfalfa. Briefly, 2% Zn_3P_2 SRO groats were broadcast using Spyker® Model-75 Spreaders (Spyker Co., N. Manchester, Indiana). Approximately 2 lb. of this bait was also spread onto a 36 ft^2, 0.25 in. wire-mesh-covered plot. Samples of bait were then collected immediately after passage through the spreader, as well as on 1, 7, and 14 days after exposure to soil/weather conditions at the test site. Bait samples were stored in plastic bags and later analyzed for Zn_3P_2.

Results showed the temporal course of rodenticide biodegradation. Interestingly, of the 2.0% Zn_3P_2 comprising the test bait, 0.2% was "knocked off" of the

SRO groats due to the mechanical action of the spreader—1.8% Zn_3P_2 was actually present on broadcast bait; that is, ~10% of the available Zn_3P_2 was dislodged from the groats during broadcast. Analyses of Day 1, 7, and 14 samples also showed that ~30% loss had occurred between Days 1 and 7, with ~87% loss of a.i. noted by Day 14. No precipitation occurred during Days 1 to 7, but 1.01 in. of rainfall during Days 7 to 14—baits were essentially neutralized by Day 14. Although the reasons for the Day 1 to 7 loss is unknown, it could be attributable to a combination of: 1) soil pH (i.e., slightly acidic, 6.0 pH); and 2) dew (i.e., occurred nightly during the study and could have dripped from plants onto baits). Use of "bait-weathering" plots are recommended as standard practice in such product-performance studies.

Benefit:Cost Analysis of Zn_3P_2 Broadcasts

Sterner et al. (in review) developed a computer program to examine the economics of broadcasting 2% Zn_3P_2 SRO groat baits to control voles in alfalfa. Ratios were computed relative to the 1996 U.S. average alfalfa yield of 3.27 tons/ac. and price of $94.12/ton (USDA 1997). The benefit:cost ratio was computed as:

Benefit:Cost Ratio = Savings (US $) ÷ Costs (US $).

Iterative runs of the program estimated costs/savings for all combinations of varied percentages of crop loss (5, 10, 15, 20, 25, 30%), rodenticide efficacy (75, 80, 85, 90, 95%), and application fee ($1, 2, 3, 4, 5, 6, 7, 8, 9, 10/ac.). The program assumed that outlays had to be recovered in a single cutting.

Benefit:cost ratios ranged between 0.44 and 4.78; these occurred for the projections of 5% loss x 70% efficacy x $10.00/ac. fee and 25% loss x 95% efficacy x $1.00/ac. fee, respectively. In general, ratios ≥2.0 occurred when crop loss was ≥15% and efficacy was ≥85%, irrespective of application fees. As expected, least expensive bait applications involve aerial and all-terrain-vehicle (ATV) broadcasts.

CONCLUSIONS

"Spinoff" from Bait Surcharge Program funded research to register Zn_3P_2 for broadcast in alfalfa has afforded diverse methodological and economical benefits. These include: 1) use of sieved-dirt plots and pre-bait particle removals can aid timing of Zn_3P_2-bait broadcasts and Zn_3P_2 efficacy; 2) use of these same plots can provide indices of bait distribution, bait removals, and target/non-target avian activity to confirm/disconfirm the effectiveness of Zn_3P_2-bait broadcasts; 3) use of a bait-weathering plot and periodic Zn_3P_2-bait analyses can document the time course of Zn_3P_2-bait biodeterioration; and 4) theoretical economic projections suggest that costs of aerial and ATV bait broadcasts can be recovered in a single cutting if vole damage exceeds 15% and vole control exceeds 85%.

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