HAND BAITING EFFICACY OF CHLOROPHACINONE AND DIPHACINONE GRAIN BAITS TO CONTROL VALLEY POCKET GOPHERS

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ABSTRACT: Valley pocket gophers (*Thomomys bottae*) cause considerable damage each year to a variety of crops. In the fall of 1997, efficacy data were collected after the hand placement of anticoagulant grain baits into underground burrows of Valley pocket gophers in northern California. Twenty-four Treatment Units (TUs) were divided into one of four treatment groups: 1) 0.01% diphacinone; 2) 0.005% diphacinone; 3) 0.01% chlorophacinone; and 4) 0.005% chlorophacinone grain baits. Each treatment group contained five treated TUs and one control TU. Active burrow systems were hand baited with the respective baits. Efficacy was determined through use of the open-hole index and radio telemetry. Neither the 0.005% or 0.01% chlorophacinone or diphacinone grain baits met the Environmental Protection Agency's 70% standard for verifying efficacy of rodenticides. Potential reasons for the low efficacy of less than 10% for the four treatment groups are discussed.

KEY WORDS: animal damage, anticoagulants, chlorophacinone and diphacinone rodenticides, *Thomomys bottae*, Valley pocket gophers

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INTRODUCTION

Pocket gophers are a major detriment to irrigated alfalfa production in California (Lee et al. 1990), New Mexico (Matschke, pers. comm.), and Arizona (Tickes et al. 1982) and cause reforestation losses on hundreds of thousands of acres each year (Campbell et al. 1992). Improvements in controlling pocket gophers are necessary to alleviate crop losses.

This study collected data on the 0.005% and 0.01% concentrations of diphacinone and chlorophacinone grain baits for submission to the Environmental Protection Agency (EPA) in support of product reregistration for these baits to control Valley pocket gophers. Amendments to the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) in 1988 mandated reregistration of a number of pesticides traditionally used for controlling wildlife damage, including chlorophacinone and diphacinone. The EPA guidance document recommends species-specific mortality data demonstrating 70% or greater mortality of the target species.

Chlorophacinone and diphacinone are classified as anticoagulants and act by reducing the ability of blood to clot. Anticoagulants must be consumed over a period of several days because they accumulate in the liver and dissipate over a period of time (Fagerstone and Schafer 1997). The objectives of this study were to determine the efficacy of two chlorophacinone and diphacinone concentrations on grain baits for controlling populations of Valley pocket gophers. The null (H_0) hypothesis tested was: Valley pocket gopher mortality does not differ among animals baited with either 0%, 0.005%, or 0.01% chlorophacinone or diphacinone oat groat baits.

Efficacy data were determined through use of the open-hole index (Richens 1967; Barnes et al. 1970). The open-hole index measures the presence or absence of a pocket gopher within an underground burrow system by relying on the gopher's propensity to close any breached burrow within its home range. Activity in a burrow system can be determined by opening burrows in the system, then returning 24 and 48 hours later to see if the openings have been closed with soil. Radio telemetry data were used as supporting data and to collect individuals for post treatment residue analysis.

METHODS

This study was conducted in October and November of 1997 within the range of the Valley pocket gopher in northern California, Siskiyou County. The study site occurred in the southwest corner of Butte Valley, 5.6 km (3.5 miles) southwest of Macdoel (Sec. 25 and 26, T46N R2W) at an elevation of approximately 1295 m (4,250 ft). The study area consisted of an overhead sprinkler-irrigated alfalfa field. The field was flat and the study occurred just after the final alfalfa cutting for the year.

Twenty-four rectangular Treatment Units (TUs) were established in fields supporting high densities of Valley pocket gophers. Each TU was a minimum of 0.4 ha (1 acre), with pin flags defining boundaries. To reduce post-treatment pocket gopher movement, a buffer zone was constructed by defining a line parallel to each side of the TU 15.2 m (50 ft) out from the boundaries. Each TU and associated buffer was a minimum of 0.89 ha (2.19 acres). A minimum distance of 50 m (160 ft) separated any two TUs.

The primary purpose of the radio telemetry was to recover carcasses for chemical residue analysis and secondarily to provide efficacy data. Pocket gophers were captured on plots to be treated using tube traps inserted into underground burrow systems at active pocket gopher sites. Traps were made from 12" PVC pipe, 2" diameter, with a cap on one end and a one-way door at the other end made from sheet metal with a wire hinge.

Captured individuals were immobilized with Metafane® (methoxyflurane) and marked with a unique number. The sex was determined by palpation, individuals were weighed, and a radio transmitter collar was attached to the neck. Animals wearing radio collars were located daily; these locations were marked by a pin flag. A gopher showing no signs of movement for three consecutive days was excavated and later submitted for post-treatment chemical residue analysis.

Sample plots were established on the TUs for the purpose of conducting the open-hole index. Fresh mounds and feeder plugs were flagged on the TUs until 15 active sample plots could be established in each TU. Each sample plot was circular in shape with a 5.2 m (16.8 ft) radius totaling 0.008 ha (1/50 acre). The center of each sample plot was marked with a numbered pin flag. Burrow systems were probed and opened pretreatment. Forty-eight hours later, probed holes were assessed to confirm that each TU had 15 active sample plots.

The 24 TUs were randomly assigned to one of four treatments (0.01% chlorophacinone, 0.005% chlorophacinone, 0.01% diphacinone, and 0.005% diphacinone grain baits). This divided the TUs into four equal treatment groups, with each group containing six TUs (Table 1). One TU from each group was randomly selected to receive the 0% grain bait (control). Bait concentrations were prepared on steamed, slightly crimped oat groats by Rodent Control Outfitters (P.O. Box 191, Harrisburg, Oregon 97446). All four anticoagulant baits were prepared according to California's Confidential Statement of Formula for each chemical and concentration. The California Department of Food and Agriculture requires toxic baits to be dyed so they are identifiable in the field; anticoagulant baits are dyed blue. Treatment baits in this study received the DuPont oil blue A dye at a concentration of 0.125%. The control was formulated in the same manner as the treatment bait only without both the toxicant or dye.

Within each TU, bait was applied in: 1) the 15 sample plots; 2) the active sites inside the TU but outside the sample plots; and 3) active sites in the buffer zone. Each active site was probed until a burrow was located. One-half cup of bait was placed into each probed hole. To prevent soil from covering the applied bait, the probed hole was closed with a paper plug and then covered with soil. We maximized the number of baited sites on each sample by baiting as many burrows as possible that could be found.

Ten days post treatment, burrow systems were reopened on the sample plots. Forty-eight hours later, an examination of all opened holes (open-hole index) was made to determine if pocket gophers had plugged the holes with soil. A plugged hole indicated that the burrow system was active. Conversely, a hole remaining open was classified as inactive. The open-hole index measured efficacy of the chlorophacinone and diphacinone grain baits to control Valley pocket gophers.

RESULTS

Sixty-two pocket gophers were equipped with radio transmitters on the treated TUs. Only one marked individual died during the pretreatment period. Fifteen radio transmitters were allotted to each of the four groups. Two extra radio transmitters were allotted to the last group treated, 0.005% diphacinone grain bait. Forty-eight of the 61 radio-collared pocket gophers remained alive and active post treatment. Four gophers died as a result of predation, two lost their radio collars, and seven died due to the treatments (Table 2). Of the seven that died due to anticoagulant poisoning, none was recovered on the 0.01% diphacinone TUs, one was recovered on the 0.005% diphacinone TUs, five were recovered on the 0.01% chlorophacinone TUs, and one was recovered on the 0.005% chlorophacinone TUs.

Overall, 3,733 holes were opened and baited within the four treatment groups. Three hundred sixty sample plots were baited (15 sample plots per TU) with an average of four bait sites per sample plot, depending on pocket gopher activity.

For the 0.01% diphacinone treatment, 52.1 kg (114.7 lb.) of treated bait was applied to the 5 TUs, with an average of 10.4 kg. (22.9 lb.) per TU. Post treatment, pocket gophers remained active on 73 (97.3%) of the 75 treated sample plots and on 15 of the 15 (100%) sample plots on the control TU (Table 1). On the 5 treated TUs, pocket gophers plugged 277 (89.6%) of 309 holes opened on the 75 sample plots. On the control, 6.5 kg (14.3 lb.) of 0% bait was applied and pocket gophers plugged 44 (89.8%) of 49 holes that were opened on the 15 sample plots.

For the 0.005% diphacinone treatment, 53.5 kg (117.9 lb.) of treated bait was applied to the 5 TUs, with an average of 10.7 kg. (23.6 lb.) per TU. Post treatment, pocket gophers remained active on 70 (93.3%) of the 75 treated sample plots and on 14 of the 15 (93.3%) sample plots on the control TU (Table 1). On the 5 treated TUs, pocket gophers plugged 235 (78.3%) of 300 holes opened on the 75 sample plots. On the control, 9.2 kg. (20.3 lb.) of 0% bait was applied and pocket gophers plugged 54 (80.6%) of 67 holes that were opened on the 15 sample plots.

For the 0.01% chlorophacinone treatment, 43.8 kg (96.4 lb.) of treated bait was applied to the 5 TUs, with an average of 8.8 kg. (19.3 lb.) per TU. Post treatment, pocket gophers remained active on 74 (98.7%) of the 75 treated sample plots and on 15 of the 15 (100%) sample plots on the control TU (Table 1). On the five treated TUs, pocket gophers plugged 250 (78.9%) of 317 holes opened on the 75 sample plots. On the control, 8.6 kg. (18.9 lb.) of 0% bait was applied and pocket gophers plugged 66 (82.5%) of 80 holes that were opened on the 15 sample plots.

For the 0.005% chlorophacinone treatment, 49.5 kg (108.8 lb.) of treated bait was applied to the 5 TUs, with an average of 9.9 kg. (21.8 lb.) per TU. Post treatment pocket gophers remained active on 73 (97.3%) of the 75 treated sample plots and on 12 (80.0%) of the 15 sample plots on the control TU (Table 1). On the five treated TUs, pocket gophers plugged 288 (83.5%) of 345 holes opened on the 75 sample plots. On the control, 9.2 kg. (20.3 lb.) of 0% bait was applied and pocket gophers plugged 55 (75.3%) of 73 holes that were opened on the 15 sample plots.

The open-hole index resulted in a 2.7% reduction in activity for the 0.01% diphacinone grain bait treatments and a 6.7% reduction for the 0.005% grain bait

Table 1. Efficacy of the various grain bait treatments used to control Valley pocket gophers, measured by the open-hole index, Macdoel, CA, 1997.

Treatment	Treatment Unit (TU)	No. (%) of post treatment active sample plots
0.01% diphacinone	1	15/15 (100)
0.01% diphacinone	2	15/15 (100)
0.01% diphacinone	3	13/15 (86.7)
0.01% diphacinone	8	15/15 (100)
0.01% diphacinone	13	15/15 (100)
0% Control	10	15/15 (100)
0.005% diphacinone	4	13/15 (86.7)
0.005% diphacinone	5	15/15 (100)
0.005% diphacinone	17	12/15 (80.0)
0.005% diphacinone	19	15/15 (100)
0.005% diphacinone	21	15/15 (100)
0% Control	14	14/15 (93.3)
0.01% chlorophacinone	12	14/15 (93.3)
0.01% chlorophacinone	18	15/15 (100)
0.01% chlorophacinone	20	15/15 (100)
0.01% chlorophacinone	22	15/15 (100)
0.01% chlorophacinone	24	15/15 (100)
0% Control	9	15/15 (100)
0.005% chlorophacinone	6	15/15 (100)
0.005% chlorophacinone	7	15/15 (100)
0.005% chlorophacinone	15	15/15 (100)
0.005% chlorophacinone	16	14/15 (93.3)
0.005% chlorophacinone	23	14/15 (93.3)
0% Control	11	12/15 (80.0)

Table 2. The fate of radio collared pocket gophers by treatment group and sex, Macdoel, CA, 1997.

	0.01% diphacinone		0.005% diphacinone		0.01% chlorophacinone		0.005% chlorophacinone		
	Male	Female	Male	Female	Male	Female	Female	Male	Total
Survived	7	5	7	4	7	3	3	12	48
Predation	2	1	0	1	0	0	0	0	4
Lost Radio	0	0	0	1	0	0	1	0	2
Died	0	0	1	0[a]	4	1	1	0	7
Total # collared	9	6	8	6	11	4	5	12	61

[a]One pretreatment death not tabulated here because it was not due to the treatment.

Table 3. Summary of bait efficacy data (% reduction in activity) averaged by treatment groups, Macdoel, CA, 1997. Percent reduction required by EPA for reregistration is 70%.

	% Reduction	
Treatment Group	Treatment Units Averaged	Control Plot
0.01% diphacinone	2.7	0
0.005% diphacinone	6.7	6.7
0.01% chlorophacinone	1.3	6.7
0.005%chlorophacinone	2.7	20.0

treatments, with reductions in the 0% control TUs of 0% and 6.7%, respectively. The open-hole index resulted in a 1.3% reduction in activity in the 0.01% chlorophacinone grain bait treatment and a 2.7% reduction for the 0.005% chlorophacinone grain bait treatment, and control TU activity was reduced 6.7% and 20%, respectively (Table 1). The reduction observed on the treated TUs during the pre- and post-baiting periods reflects both bait related deaths and natural mortality, while reduction in activity on the control TUs solely reflects natural mortality.

The overall efficacy values for chlorophacinone and diphacinone grain baits, as estimated by the open-hole index, were extremely low and did not approach the EPA's suggested 70% mortality. No statistical analyses were performed because the efficacy data observed in this study did not approach EPA's requirement of 70%.

DISCUSSION

In this study, both the open-hole index and the mortality among the radio-equipped pocket gophers yielded estimates of less than 15% reduction in pocket gopher numbers following the application of both chlorophacinone and diphacinone grain baits at the 0.005% and 0.01% concentrations. This efficacy falls well below the minimum 70% standard for rodenticides established by the EPA. The factor(s) contributing to this low percentage of population reduction are unknown.

From previously published reports we know that both toxicants effectively control rodent species such as northern pocket gophers (*Thomomys talpoides*), Valley pocket gophers, and plains pocket gophers (*Geomys bursarius*) (Baroch and Poche 1986; Vossen and Gadd 1990; Campbell et al. 1992). Campbell et al. (1992) reported 62% reduction in Valley pocket gopher activity one month post baiting with a 0.005% diphacinone grain bait imbedded in paraffin. They found that most pocket gophers died within 28 days, but that the diphacinone baits did not seem to affect them before about 20 days. In our study, we monitored activity to 12 days post baiting. Perhaps these baits take longer to kill gophers. However, Baroch and Poche (1986) reported efficacies of 100% and 95% with plains and northern pocket gophers, respectively. They reopened holes 10 to 13 days post baiting. This is similar to our study in which we opened holes 10 days post baiting and did our final counts at 12 days post baiting.

The question arises as to whether 1/2 cup of bait in each burrow was a sufficient amount of bait to kill gophers. We not only baited an average of four bait sites per 1/50 acre plot, we also baited every active mound within the one acre TU as well as the buffer zone. Baroch and Poche (1986) applied less that 1/4 cup of bait per bait site and report a much greater efficacy than us. It is unlikely that gophers did not receive an adequate amount of bait.

Another potential reason for the low efficacy may be a taste aversion to the baits. Post baiting, we observed many sites in which bait had been expelled from the burrow system. In a previous study, Valley pocket gophers consumed an oat groat bait formulated with just the DuPont oil blue A as a biomarker at 1.6% concentration (Matschke et al. 1999). Bait was applied after the final cutting of alfalfa and a tablespoon of bait was applied at active burrow systems. Gophers were trapped and examined internally for the presence of blue dye in their fat. On the five TUs treated, 203 pocket gophers were trapped and 109 (53.7%) were marked.

Lessened bait acceptance was demonstrated by northern pocket gophers when 1.6% DuPont oil blue A oat groat bait was applied to active burrow systems in September after the final alfalfa cutting (Matschke et al. 1994a). One hundred percent of bait sites were moved by gophers but when trapped, only 7 of 20 (35%) were marked with the dye in their subcutaneous fat. However, in both of these bait acceptance studies the quantity of bait consumed by each marked individual was not determined.

When developing the DuPont oil blue A as a biomarker, a laboratory study showed that it acts as a repellent to northern pocket gophers when formulated at the 1.6% concentration (Matschke et al. 1994b). Bait consumption was significantly less ($p=0.0055$) for pocket gophers given the 1.6% bait than for the control gophers receiving plain oat groats. The quantity of 1.6% bait consumed averaged 2.48 g ($SE=0.25$) per day and the quantity of the control bait consumed averaged 4.69 g ($SE=0.68$ g).

When oat groat baits formulated with 0.125% DuPont oil blue A dye were fed to domestic white mice (*Mus musculus*) and deer mice (*Peromyscus* spp.) with the 0.01% and 0.005% chlorophacinone and diphacinone, the two species consumed the baits and mortality for both toxicants at both concentrations exceeded the 70% minimum standard for rodenticides established by the EPA (McCann and Matschke 2000; McCann 2000). However, the same baits fed to domestic Norway rats (*Rattus norvegieus*) were rejected with extremely low efficacy resulting (Matschke, pers. comm.).

Before conducting further research on these two anticoagulant toxicants, we suggest evaluating the repellency of a 0.125% DuPont oil blue A oat groat bait on Valley pocket gophers. It appears from previous studies that acceptance of the DuPont oil blue A dye may be species specific. Further research is needed to determine why a low efficacy resulted in this study. Laboratory tests evaluating the efficacy of 0.005% and 0.01% chlorophacinone and diphacinone grain baits, as well as the DuPont oil blue A dye would help determine efficacy and bait acceptance.

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