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Authors

Baldwin, Roger A.
Quinn, Niamh

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The Applicability of Burrow Fumigants for Controlling Belding's Ground Squirrels in Alfalfa

Roger A. Baldwin and Niamh Quinn

Kearney Agricultural Research & Extension Center, University of California, Parlier, California

ABSTRACT: Rodenticides are often used to control burrowing rodents but have not been overly efficacious for Belding's ground squirrels due to poor bait acceptance. This has left alfalfa growers searching for alternative options for controlling this rodent species. As such, we tested aluminum phosphide and gas cartridge burrow fumigation in an alfalfa field in Butte Valley, CA, to determine if either of these approaches were efficacious and cost effective for controlling Belding's ground squirrels. A comparison of the number of burrows treated and the number of burrows reopened 48-hours post-treatment indicated that both burrow fumigants were highly effective (aluminum phosphide = 94-98%, gas cartridges = 100%). The average cost per application was \$1.05 and \$2.92 for aluminum phosphide and gas cartridges, respectively. Given the almost 3-fold difference in cost of application between the 2 approaches, aluminum phosphide appears to be the more practical approach for Belding's ground squirrel control. Although we currently lack an approach for estimating the amount of damage that Belding's ground squirrels are likely to cause to an alfalfa field, it seems plausible that burrow fumigation could be a cost effective approach to reduce damage caused by this species, particularly if long-term control can be obtained. Possible long-term management options for Belding's ground squirrels are discussed.

KEY WORDS: aluminum phosphide, Belding's ground squirrel, burrow fumigant, gas cartridge, *Spermophilus beldingi*

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INTRODUCTION

The Belding's ground squirrel (*Spermophilus beldingi*) is a significant pest of alfalfa in the northeastern portions of California and eastern Oregon. Primary damage caused by Belding's ground squirrels includes the direct loss of production from forage consumption and burrow construction with estimated losses ranging from 17.1-65.9% (Sauer 1976, Kalinowski and deCalesta 1981, Sauer 1984, Whisson et al. 1999). Ground squirrels cause further problems through burrow damage to farm equipment, reduced hay quality due to soil from burrows being captured in hay bales, and through increased weed density due to ground squirrel foraging thinning alfalfa stands.

Historically, Belding's ground squirrels were effectively controlled through the use of Compound 1080 (sodium monofluoroacetate)-treated cabbage. However, in 1990, Compound 1080 was deregistered for this use (Whisson et al. 2000). Alfalfa growers have been searching for a viable control option since this time. Grain-based anticoagulant and zinc phosphide baits have been tested, but results have not been overly positive (e.g., Sullins and Verts 1978, Matschke et al. 1999a,b). Furthermore, they are not registered for ground squirrel control in alfalfa limiting their use to adjacent non-crop areas.

Other control options have included shooting, exclusionary fencing, and burrow fumigation. Shooting is currently the primary method of control for Belding's ground squirrel (S. Orloff, UC Cooperative Extension, pers. commun.), although the efficacy of this approach is unknown. Exclusionary fencing appears to be effective at keeping ground squirrels out of fields, but the cost can be quite high (Whisson et al. 2000). Burrow fumigants such as aluminum phosphide, gas cartridges, and acrolein can also be expensive control options (Whisson et al. 2000). Acrolein has proven to be an effective burrow

fumigant for Belding's ground squirrels (Clark 1994) but is no longer registered for use on burrowing rodents in California. Efficacy data for aluminum phosphide and gas cartridges are limited for Belding's ground squirrels, but these materials have proven effective for California ground squirrels (*Spermophilus beecheyi*; Salmon et al. 1982, Baldwin and Holtz 2010). If these burrow fumigants are efficacious and cost effective, then they would provide a viable option for Belding's ground squirrel control in alfalfa. Therefore, our objectives for this study were to: 1) determine the efficacy of aluminum phosphide and gas cartridge fumigation for controlling Belding's ground squirrels, and 2) determine the practicality and cost effectiveness of these burrow fumigants for controlling this damaging pest.

METHODS

For trial purposes, we identified an alfalfa field in Butte Valley, Siskiyou County, CA, that was home to a large Belding's ground squirrel population. Our study site was established in spring 2011 to allow us to treat three 0.8-ha plots with an unregistered rodenticide while treating the outlying buffers with aluminum phosphide pellets (Fumitoxin[®], D & D Holdings, Inc., Weyers Cave, VA) and gas cartridges (U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Riverdale, MD; Figure 1). We treated a larger proportion of the buffer with aluminum phosphide given lower material costs associated with this material. However, we did not treat one section of the buffer due to the cessation of the rodenticide trial (Figure 1). This resulted in a total treatment area of 4.4 ha for aluminum phosphide and 2.3 ha for gas cartridges. We are not presenting the findings from the rodenticide trials here, but rather will focus on results from the fumigation trials.

For aluminum phosphide treatments, we placed 15

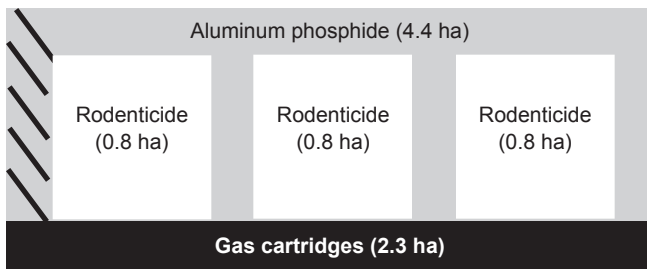


Figure 1. Illustration of treatment area for Belding's ground squirrel study. The gray areas represent sites treated with aluminum phosphide, black areas represent sites treated with gas cartridges, white areas indicate sites for rodenticide application, while gray areas with black diagonal bars indicate sites not treated. The purpose for this design is provided in text.

to 20 pellets as deep into the burrow as possible. We then plugged the opening with crumpled newspaper and covered the newspaper and opening with soil. For gas cartridges, we treated all burrow openings in the gas cartridge study area by lighting the cartridges and inserting into the burrow system. The cartridges were shoved as far into the burrow as possible using a shovel handle, and the openings were covered with soil, making sure that no smoke was detected escaping from the opening. If smoke was detected from another opening, that opening was also covered with soil.

To determine treatment costs, we recorded the number of burrow systems treated for each burrow fumigant. We also recorded the length of time required to treat the entire area for each burrow fumigant. This allowed us to determine the average application time required for each burrow fumigant. This value was then multiplied by an hourly labor fee of \$10.00/hour to estimate hourly labor costs. This labor cost was then added to the material cost per treatment of aluminum phosphide (\$0.39) and gas cartridges (\$1.67) to estimate the average treatment cost per burrow system.

We assessed efficacy for each of these burrow fumigants through burrow counts. This was done in two ways. First, 48 hours after applying the fumigants, we checked for any plugged burrows that had been reopened. This provided us with a total count. This efficacy value could have overinflated the true value, given that we treated all burrow openings (i.e., some of the burrows we treated were likely inactive and therefore the odds of them being reopened would be negligible). As such, we also identified a representative sample of burrow systems that we felt positive were active to provide a less biased estimate of efficacy. Active burrow systems were identified by observing recent activity around and within the burrow or by observing ground squirrels within the burrow system. These active burrow systems were flagged before treatment to allow us to ascertain activity associated with these burrow systems 48 hours post-treatment.

RESULTS

We treated 1,725 burrow systems with aluminum phosphide and 297 burrow systems with gas cartridges. The density of burrow systems in each study area was 267 and 129 burrows per ha for aluminum phosphide and

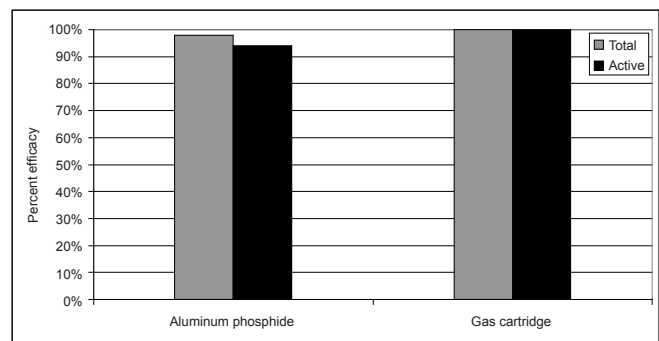


Figure 2. Percent efficacy for applications of aluminum phosphide and gas cartridges for Belding's ground squirrel control in Siskiyou County, CA, during spring 2011. Efficacy values were derived from a comparison of the number of treated burrows and the number of reopened burrows 48 hours post-treatment for all burrow openings within the treatment areas (total) and for a subset of burrow openings that were verified active (active).

gas cartridges, respectively. For the aluminum phosphide treatment area, 34 burrow systems were reopened, while 0 were reopened in the area treated with gas cartridges. We also flagged 51 and 12 burrow systems in the aluminum phosphide and gas cartridge treatment areas, respectively, that we determined were active. Of these, 3 burrow systems were reopened in the aluminum phosphide treatment area; none were reopened in the area treated with gas cartridges. Efficacy was 100% for gas cartridges, while aluminum phosphide ranged from 94-98% depending on the sampling technique used (Figure 2).

The time, associated labor costs, and material costs were all substantially lower for aluminum phosphide than for gas cartridges, which resulted in treatment costs that were almost 3 times as great for gas cartridges (Table 1). By incorporating average yields, current revenue per metric ton of alfalfa, and yield losses from a moderate to heavy infestation of Belding's ground squirrel (Whisson et al. 1999), we estimated current revenue losses of \$582/ha for the first and second cuttings combined (Table 2). At this rate of damage, 554 and 199 burrow systems could be treated with aluminum phosphide and gas cartridges, respectively, to break even.

DISCUSSION

Reducing or eliminating the number of Belding's ground squirrels in alfalfa is highly desirable given the substantial damage they can cause to this commodity (17.1-65.9%; Sauer 1976, Kalinowski and deCalesta 1981, Sauer 1984, Whisson et al. 1999). Burrow fumigation provides one option for controlling these pests. Results from this investigation indicate that both aluminum phosphide and gas cartridges are highly effective at controlling Belding's ground squirrels. This is contrary to what was reported in an earlier study, which reported efficacy values of 30-40% for both materials (Orloff et al. 1995). We are unsure why the previous study yielded such low efficacy. Perhaps soil moisture was not sufficient at that time to effectively hold gases within the burrow system. Alternatively, their study site may have been comprised of naturally porous

Table 1. The average time, associated labor cost, material cost, and total cost to apply aluminum phosphide and gas cartridges per burrow opening for Belding's ground squirrels.

	Time	Labor cost	Material cost	Total cost
Aluminum phosphide	3 min, 58 sec	\$0.66	\$0.39	\$1.05
Gas cartridge	7 min, 28 sec	\$1.25	\$1.67	\$2.92

Table 2. Average alfalfa production (metric tons/ha), average revenue per metric ton (price/metric ton), estimated percent loss of production from a moderate-to-high infestation (percent loss/ha), and estimated revenue loss (revenue loss/ha) from Belding's ground squirrels for first and second cuttings of alfalfa in Siskiyou County, CA, during spring 2011.

	Metric tons/ha	Price/metric ton	Percent loss/ha	Revenue loss/ha
1st cutting	5.6	\$221	35%	\$433
2nd cutting	4.5	\$221	15%	\$149
			Total:	\$582

or fractured soils that did not effectively contain the toxic gases. Our results are in line with other studies on the efficacy of these two burrow fumigants for California ground squirrels (aluminum phosphide = 97-100%, gas cartridges = 60-86%; Salmon et al. 1982, Baldwin and Holtz 2010). At a minimum, it appears that when used under appropriate conditions, aluminum phosphide and gas cartridges are effective tools for controlling Belding's ground squirrels.

Although efficacious, these fumigants will not be widely used if they are not cost effective. In our study, aluminum phosphide was clearly more cost effective than the gas cartridge, as application costs were nearly 1/3 that of gas cartridges. Given that the increase in efficacy of gas cartridges over aluminum phosphide was relatively minimal, it is likely that most growers will use aluminum phosphide over gas cartridges, given their substantially lower application costs. That being said, aluminum phosphide is a Restricted-Use material while gas cartridges are not, so individuals who want to use burrow fumigation, but are not certified to use Restricted-Use pesticides, could still use gas cartridges to effectively control Belding's ground squirrels. Alternatively, if there are only a few burrows to treat, gas cartridges may be more practical, given the less onerous restrictions on their use.

Although aluminum phosphide was clearly cheaper to apply than gas cartridges, it still can be a costly material to apply, given the labor-intensive application process. In our study, we noted average application times of almost 4 minutes (Table 2). This value could likely be reduced with greater application experience, as similar estimates for California ground squirrels averaged 1.4-1.6 minutes per burrow system (Salmon et al. 1982). Increasing this application speed would substantially reduce per burrow treatment costs and would increase the number of burrows that could be treated cost effectively. Still, even at application rates and damage estimates provided in this study, a grower could treat 554 burrows per ha and still break even financially. This is a high number and indicates that burrow fumigation could be a cost effective approach for controlling Belding's ground squirrels even at relatively high densities. Unfortunately, data is lacking on the relationship between the number of Belding's

ground squirrel burrow openings and the estimated damage associated with these individuals. Knowing this information would allow us to determine the viability of any control program and is worthy of further investigation.

The viability of any burrowing rodent control program is impacted by the grower's ability to keep pest populations low. Therefore, incorporating a burrow fumigation control program over a larger area would increase the cost effectiveness of such a program by reducing the impact of immigration into areas where ground squirrels have been removed. Neighbor cooperation is usually key for such a successful program and should be encouraged to increase the long-term effectiveness of a ground squirrel control program. Alternatively, if you cannot control ground squirrels on adjacent properties (e.g., uncooperative neighbors, adjacent to natural areas, etc.), exclusionary fencing could be considered. Whisson et al. (2000) explored the use of a fence constructed of roofing iron to keep Belding's ground squirrels out of alfalfa fields. Although expensive (\$21,000 to fence a standard-size 50.2-ha circular field in 2000; Whisson et al. 2000), the construction of these fences can greatly reduce ground squirrel movement into fields. These fences can last for many years, and as such, may be cost effective in the long run. Therefore, a control program that utilizes burrow fumigation to remove ground squirrels from fields and erects exclusionary fencing to keep adjacent squirrel populations from reinvading the clean field could be one of the most cost effective long-term solutions. Such an approach could particularly be of interest where chronic problems with Belding's ground squirrels are present.

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