Evaluation of a Pressurized Exhaust Device to Control Pocket Gophers and Belding's Ground Squirrels in Alfalfa

Steve B. Orloff
University of California Cooperative Extension, Yreka, California

Abstract: Intermountain alfalfa fields are ideal habitat for burrowing rodents like pocket gophers and Belding's ground squirrel, due to an alfalfa stand life of at least 5 to 7 years and sprinkler rather than flood irrigation. Current control measures are only marginally effective and are expensive or extremely labor intensive, so many alfalfa producers have no rodent management program whatsoever. A new device called the Pressurized Exhaust Rodent Controller (PERC) was developed to control burrowing rodents using an internal combustion engine to generate and pressurize carbon monoxide that is injected into the burrow system using multiple hand-held probes. Field trials were conducted in April and May 2006 to evaluate the effectiveness of this device for controlling both pocket gophers and Belding's ground squirrels in Siskiyou County, CA. An additional gopher control study was conducted in October 2011 to evaluate a newer version of the PERC device. Gopher studies were conducted in three commercial alfalfa fields and ground squirrel studies in an alfalfa field and a dryland range field. The PERC unit was used to inject exhaust fumes into the gopher burrow system. Approximately 24 hours after treatment, the gopher burrow systems were opened. Control was estimated by assessing the number of burrow systems that remained open the following day. Using the open-hole index technique to assess gopher activity, control efficacy was calculated to be 61%, 63%, and 45% for the two 2006 studies and the 2011 study, respectively. In the Belding's ground squirrel studies, the hand-held probes were inserted into the open burrows and the burrow opening closed with soil prior to injecting the carbon monoxide exhaust. Control was assessed by determining the percentage of burrow systems that were reopened the day after treatment. Control efficacy for the two squirrel studies was calculated to be 81% and 71%. These preliminary results suggest that the injection of pressurized exhaust in gopher and squirrel burrow systems may be effective as part of an integrated vertebrate pest management program, but additional research is needed to further define the parameters required for effective control.

Key Words: alfalfa, Belding's ground squirrel, carbon monoxide, fumigation, gophers, PERC, rodent control, *Spermophilus beldingi*, *Thomomys* spp.

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INTRODUCTION

Alfalfa fields in the intermountain area of Northern California are ideal habitat for pocket gophers (*Thomomys* spp.), Belding's ground squirrels (*Spermophilus beldingi*), and meadow voles (*Microtus* spp.), and many producers consider vertebrate pest control to be one of their most significant production problems. Unlike most alfalfa production regions in California, the overwhelming majority of alfalfa in the Intermountain Region is sprinkler irrigated. Flood irrigation, which is more common in other areas, helps suppress the population of these vertebrate pests (Whisson and Salmon 2008). In addition, alfalfa stand life in the intermountain areas is typically 5 to 7 years or longer, compared to 3 to 4 years in the Central Valley or Low Desert regions of California (Orloff 1995). Intermountain alfalfa fields are typically only rotated to other crops for a year or two years maximum, and then are seeded to alfalfa again. This combination of long stand life and a short rotation between alfalfa plantings means that agricultural fields are rarely tilled; annual tillage, and especially deep tillage, would help to destroy burrow systems and reduce vertebrate pest populations. Sandy loam or loam soils are common and provide favorable conditions for burrowing rodents. Even when these vertebrate pests are adequately controlled, fields are susceptible to rapid reinvasion because intermountain alfalfa fields are often adjacent to rangeland, forested areas, or other alfalfa fields.

Pocket gophers pose a significant problem for alfalfa producers throughout the intermountain area, while the Belding's ground squirrel is typically a problem only in areas over 4,000 ft. elevation.

Gophers

Gophers feed primarily on the alfalfa roots weakening and eventually killing the plant. A yield reduction in total forage production of 38% was reported in one study (Case et al. 1979). Because gophers cause permanent stand decline, their impact on yield is permanent, lasting for the life of the alfalfa stand. Gopher mounds can smother and kill plants and often cause weed infestations; gopher burrowing activity brings untreated soil (soil from below the depth of herbicide incorporation) and weed seed to the surface, where they can germinate. The gopher mounds damage alfalfa harvesting equipment, and soil often ends up in hay bales, reducing the nutritional value and palatability of the hay to livestock.

Gopher control has been a long-standing frustration for alfalfa producers, and with the exception of aluminum phosphide, control measures have not changed significantly compared with what was reported decades ago (Marsh 1992). Aluminum phosphide is effective (Baldwin 2011), but is not commonly used because it is a restricted-use material meaning it can only be used by or under the supervision of a Certified Applicator. Because of the relatively low value of the crop and the need to access the field with farm machinery for frequent harvest, it is not economi-

cal or practical for alfalfa producers to use exclusionary techniques such as buried fences. Trapping and baiting are the most common control practices currently used in intermountain alfalfa fields for gopher control. Traps are an effective control method but are labor intensive. Most individual alfalfa fields are typically a minimum of 80 acres in size and many are much larger. Given the gopher infestation level that occurs in many intermountain alfalfa fields and the unavailability of farm labor, gopher trapping is not widely practiced, and it is usually reserved for seedling or young alfalfa fields where gopher population density is relatively low. For the same reasons, hand baiting is rarely done in large commercial alfalfa fields. The mechanical burrow builder which deposits poison bait (usually strychnine-treated grain) is commonly practiced by some producers. Control is sometimes erratic, which is oftentimes due to improper soil moisture conditions, either too wet or too dry. Reduced availability of the higher concentration of strychnine (1.8 percent) has also been an issue. In addition, the mechanical burrow builder damages some alfalfa plants and can make the field rough for subsequent equipment travel across the field.

Belding's Ground Squirrel

Like gophers, Belding's ground squirrels cause significant damage to intermountain alfalfa fields. Belding's ground squirrels build their burrow system inside the alfalfa field rather than just on field edges as does the California ground squirrel. In addition to the damage caused by their large mounds, Belding's consume the alfalfa foliage directly, dramatically reducing forage yield. First cutting yield losses averaged 1,100 pounds per acre in one study (Sauer 1984), and they ranged from 980 to 2,700 pounds per acre over the season in another study (Whisson et al. 2000).

From 1970 to 1990, the primary control method used for Belding's ground squirrel was the aerial application of the acute rodenticide Compound 1080 (sodium monofluoroacetate) on cabbage bait (Whisson et al. 2000). When Compound 1080 was deregistered in California, growers were left with few effective control measures. Control options that were available included burrow fumigation (acrolein, aluminum phosphide, or gas cartridges), anticoagulant baits, and shooting. Acrolein is no longer registered for this use. Historically, burrow fumigation with aluminum phosphide and gas cartridges has not been practiced because of the cost and/or perceived ineffectiveness. However, recent research (Baldwin and Quinn 2012) indicates these fumigants can be efficacious in some situations. Spring spot baiting/hand baiting with 0.01% chlorophacinone on steam-rolled oat groats was found to be somewhat effective when applied as soon as adult squirrels emerge from their burrow in spring and before preferred alternative forage appears (Ramey et al. 2007), but it is not available for commercial use, as it is registered for control of California grounds squirrels (*Spermophilus beecheyi*), not Belding's. Most alfalfa producers currently have no control program whatsoever or rely solely on shooting by themselves or others whom they allow on the farm for recreational shooting. This is not believed to have an appreciable long-term effect on Belding's ground squirrel population density.

Figure 1. Pressurized exhaust device (PERC) used to evaluate pocket gopher and Belding's ground squirrel control.

Development of Pressurized Exhaust Device

Farmers have attempted for decades to control burrowing rodents, primarily gophers, by connecting a hose to the exhaust system of tractors and injecting the gas into the burrow system. The practice has been partially effective but the process is time consuming and the exhaust back pressure can cause permanent damage to the tractor. In addition, exhaust exiting the muffler of a tractor is only under a few pounds of pressure, so it is not rapidly distributed throughout the burrow system. A prototype device to improve upon the concept of using exhaust to control burrowing rodents was developed in 2005 by Allen Hurlburt, CEO of H & M Gopher Control (Figure 1). The device, called the "Pressurized Exhaust Rodent Control System" or PERC machine, utilizes a 4-cycle gasoline engine to generate carbon monoxide and an air compressor to then pressurize it to approximately 110 psi. Multiple probes connected to 50-ft. hoses are then used to inject the carbon monoxide-laden exhaust into the underground burrow system.

Until this year (2012), the California Penal Code prohibited the use of carbon monoxide to euthanize mammals. In October 2011, legislation (AB 634) was passed by the California legislature and then signed by the governor to allow the use of carbon monoxide to control rodents.

Data were lacking on this effectiveness of this PERC device. The objective of this research was to evaluate the control of pocket gophers and Belding's ground squirrel using the PERC device under intermountain environmental conditions.

METHODS

Study Site Locations

Three commercial alfalfa fields in the California portion of the Klamath Basin near Tulelake were selected as the study sites for the gopher experiments. The fields had moderate levels of gopher activity. The elevation of the fields was approximately 4,050 ft. above sea level. A

Table 1. Reduction in gopher activity observed when compressed exhaust fumes were injecting into pocket gopher burrow systems using the PERC device in the spring of 2006 and fall of 2011 in Tulelake, CA.

Treatment	Tulelake A 2006		Tulelake B 2006		Tulelake 2011	
	Total # holes	Ave. % plugged	Total # holes	Ave. % plugged	Total # holes	Ave. % plugged
Untreated	44	98	70	93	102	88
Exhaust fumigation	57	38	70	34	97	49
Overall Efficacy	**61%**		**63%**		**45%**	

rangeland site in the foothills to the east of Tulelake was used for the first Belding's ground squirrel study. A large commercial alfalfa field in Butte Valley approximately 20 miles east of Macdoel, CA (Siskiyou County) was selected for the second squirrel study.

Treatment Unit Establishment

Four treatments units (TUs) were established in each of two commercial alfalfa hay fields on April 11 and April 26, 2006. An additional gopher control trial was established on October 26, 2011 to evaluate an updated version of the PERC machine, in anticipation of the legalization of the device in California. The TUs were irregular in shape and their size depended on the gopher infestation level in the field. A buffer zone of at least 40 feet was established around each TU and received the same treatment as the rest of the TU, in order to minimize gopher immigration from outside the plot into the TU. Similarly, four TUs were established in two fields to evaluate Belding's ground squirrel control. Trials were established on May 9 and 17, 2006 for the trials near Tulelake and Macdoel, respectively.

Establishing Plots and Evaluating Pocket Gopher Activity

Fields were harrowed by the farmers prior to conducting the studies to smooth out the mounds so that freshly constructed mounds and feeder plugs could be identified for the study. The two treatments, PERC-fumigated and untreated (control), were randomly assigned to the four TUs so that there were two replicates of each treatment. Treatment occurred the same day the TUs were established. Gopher tunnels were located by probing near all readily visible gopher mounds or feeder plugs. Once the tunnel was located, exhaust from the PERC device was injected into the gopher burrow by opening the valve on the probe handle for approximately 2 minutes. The PERC unit had four hoses/probes, so the operator rotated in sequence from probe to probe after approximately 2 minutes lapsed and moved on to additional burrow systems until the burrow systems associated with all the visible mounds or plugs within the TU were treated. The center mound of what appeared to be a single active gopher burrow system was flagged. To measure the efficacy of the PERC system for gopher control, the open-hole index was used. Twenty-four hours after treatment with the PERC-generated exhaust, all of the flagged burrow systems were opened. A similar number of untreated burrows were opened in the untreated TUs. An additional 24 hours after the burrow systems were opened (48 hours after the exhaust treatment), the plots were evaluated. The number of opened burrow systems closed by pocket gophers was recorded. The presence of a live gopher was assumed when the opened burrow system was plugged, based on a live gopher's propensity to close any open burrows within its home range.

Establishing Plots and Evaluating Belding's Ground Squirrel Activity

The experimental procedure used for the two Belding's ground squirrel studies was similar to that used for the gopher studies. Four TUs were established in each of the two study sites. Like the gopher studies, two TUs were treated with pressurized exhaust from the PERC unit, and two were left untreated. The probe was inserted into the open squirrel burrow entrance, and soil from the adjacent mound was gently packed around the probe to provide a seal so that the carbon monoxide did not escape the burrow system. The exhaust was injected into the burrow for approximately two minutes. The center burrow entrance for what appeared to be a single burrow system was flagged. The entrance hole was completely covered with soil after the probe was removed. A similar number of squirrel entrance holes were plugged and flagged in an untreated area. Twenty-four hours later, the number of closed squirrel burrow entrances that were reopened was recorded. The presence of a live squirrel was assumed when a closed burrow entrance had been reopened.

RESULTS

Pocket Gophers

The number of active pocket gophers in the untreated control plots varied depending on the site (Table 1). The percentage of plugged gopher holes in the untreated areas was 98%, 93%, and 88% for the three gopher studies. There were significantly fewer plugged holes in the exhaust-fumigated area. The overall efficacy of the exhaust fumigation treatment, taking into account the percent gopher occupation in the untreated plots, was calculated to be 61%, 63%, and 45% for the Tulelake A 2006, Tulelake B 2006, and the Tulelake 2011 gopher studies, respectively.

Belding's Ground Squirrels

Sixty-four percent of the untreated burrow openings were reopened in the Tulelake trial, while 51% were reopened in the Macdoel trial (Table 2). Significantly fewer of the burrow openings were reopened in the burrow systems where exhaust from the PERC device was injected into the burrow system. Overall efficacy was calculated to be 81% and 71% for the two studies.

Table 2. Reduction in Belding's ground squirrel activity observed when compressed exhaust fumes were injecting into squirrel burrow systems using the PERC device in Tulelake and Macdoel, CA in 2006.

Treatment	Tulelake 2006		Macdoel 2006	
	Total # holes	Ave. % opened	Total # holes	Ave. % opened
Untreated	175	64	153	51
Exhaust fumigation	192	12	387	15
Overall Efficacy	**81%**		**71%**	

DISCUSSION

The results of these field studies demonstrated that exhaust injected into the burrow system of gophers reduced gopher activity. The level of control was less in the 2011 study than in the earlier (2006) studies. The reason for this is unknown, but there are several potential explanations. The operator for the 2011 studies was less experienced and perhaps less adept at locating the burrow system. It is also possible, but doubtful, that soil type or moisture content was a factor, or maybe the fact that the mechanical burrow builder had been used in this field the previous spring. These could have resulted in more of the exhaust dissipating and not reaching a lethal concentration. The level of Belding's ground squirrel control observed in these trials was slightly higher than control of pocket gophers; however, additional research is needed to confirm these preliminary results.

The reduction in pocket gopher activity observed in these studies falls short of the 70% minimum standard established by the Environmental Protection Agency (EPA). However, the PERC system is considered a device and therefore does not have to meet the same criteria required for rodenticides. Other fumigants previously evaluated for pocket gopher control have also fallen short of the 70% threshold. A 58.9% reduction in gopher activity was observed with acrolein (Matshke et al. 1998). Studies with gas cartridges reported even lower reductions in pocket gopher activity, averaging approximately 17% to 22% control success. It has been suggested that efficacy increases when fumigants are forced into the burrow system by external pressure (Matshke et al. 1998). Eighty-five percent mortality (11 of 13 animals) was observed (G. Matschke, unpubl. data) when auto exhaust was pumped into the burrow system of radio-tagged plains pocket gophers (*Geomys bursarius*). This level of control is higher than was observed in this study. This emphasizes the need to quantify the concentration of carbon monoxide that occurs in the burrow system from different exhaust-generating devices and to quantify the rate of travel of the toxic gas, in order to better understand the conditions required for effective kill rates. These initial results suggest that injecting compressed exhaust into burrow systems shows promise for gopher and squirrel control. Further research is needed to define the parameters required to maximize efficacy. Multiple trips through the field with the PERC unit or combining different control measures into an integrated program will likely be necessary for satisfactory control of these rodent species.

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