FUMIGANT DISPERSAL IN POCKET GOPHER BURROWS AND BENEFITS OF A BLOWER SYSTEM

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ABSTRACT: Efforts to establish tree seedlings on sites infested with high populations of pocket gophers (*Thomomys* spp.) can be futile unless population control measures are implemented. Fumigants are a possible means to reduce pocket gopher populations although the efficacy of fumigants on reforestation sites has been minimal. We conducted a series of experiments to monitor the movement of carbon monoxide through burrow systems and to assess the potential benefits of a blower system. In the first experiment, carbon monoxide was introduced to an artificial burrow system by burning either one or two gas cartridges concurrently or consecutively. The blower was tried at different speeds for varied durations. Carbon monoxide concentration was monitored with sensors that had a detection range from 0 to 5,000 parts per million. Burning the cartridges without the blower was not effective in distributing carbon monoxide. The most effective fumigant dispersal occurred when the blower was used at a low speed for only the period while a cartridge was burning. Burning two cartridges simultaneously was the most effective burn configuration. Results from a second experiment, using vacated pocket gopher burrows instead of an artificial system, were similar to those recorded for the first experiment. Subsequently, we conducted field trials using a blower to disperse carbon monoxide to reduce pocket gopher populations on reforestation sites. These trials did not demonstrate a reduction in pocket gopher activity. We speculate this was because existing burrow plugs prevented the gas from dispersing through the systems or because pocket gophers rapidly blocked burrows when they detected the gas, thus preventing exposure to lethal gas concentrations.

KEY WORDS: carbon monoxide, fumigants, gas cartridges, pocket gopher, reforestation

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INTRODUCTION

Pocket gophers (*Thomomys* spp.) are an impediment to reforestation efforts in the Pacific Northwest (Capp 1976; Crouch 1986; Marsh and Steele 1992). Efforts to establish tree seedlings on sites infested with pocket gophers can be futile unless protective measures are implemented. In preferred forest-habitat, a high population of pocket gophers (37 to 62 per ha) can damage a significant portion of conifer seedlings (Marsh and Steele 1992). Annual seedling losses are reported to vary from 5% to 50% (Barnes 1973). Plant succession post timber harvest often create favorable pocket gopher habitat and encourage high populations. In some extreme cases, where direct pocket gopher control is not possible or is anticipated to be ineffective, harvest may be ill advised because successful reforestation is too uncertain (Marsh and Steele 1992).

Pocket gophers commonly prune roots of seedlings and girdle or clip seedling stems (Nolte and Otto 1996). Small seedlings, less than 0.75 cm in diameter, are the most vulnerable. The stems generally are clipped at or near ground level and pocket gophers may pull harvested seedlings into their burrows. Pocket gophers also prune the roots and girdle the stems of larger trees. Extensive above-ground girdling is fairly easy to detect. Damage to roots, however, may go unnoticed until seedlings tip over or become discolored. Nonlethal damage causes poor overall growth, shortened needles, reduced internodes, premature needle drop, and needle discoloration (Marsh and Steele 1992). Several tree species are vulnerable to damage, including ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), Jeffrey pine (*Pinus jeffreyi*), firs (*Abies* spp.), Douglas-fir (*Pseudotsuga menziessi*) and Engelman spruce (*Picea engelmannii*) (Cunutt 1970; Barnes 1973).

Management practices implemented to reduce damage inflicted by pocket gopher include habitat manipulation, such as herbicide treatments (Keith et al. 1959; Hansen and Ward 1966); silvicultural practices, such as planting immediately after logging, minimizing disturbance of a site after logging or selective cutting (Anderson 1976; Crouch 1986; Marsh and Steele 1992); physical exclusion devices (Hooven 1971; Anthony et al. 1978); trapping (Crouch and Frank 1979; Smeltz 1992); fumigation (Sullius and Sullivan 1993); repellents (Sullivan 1987; Sullivan et al. 1990); and rodenticides, such as strychnine bait (Marsh and Howard 1978). Except for strychnine, these methods are generally difficult and slow to implement, as well as expensive, and are often ineffective at reducing damage (Anthony et al. 1978; Marsh and Steele 1992). Accordingly, strychnine baiting is widely used to reduce pocket gopher populations in areas targeted for reforestation (Chase et al. 1982; Teipner et al. 1983; Marsh 1992). Additional means to effectively reduce pocket gopher damage to seedlings need to be identified.

Fumigants have been effectively used to reduce populations of some fossorial mammals (Marsh 1995), although limited efficacy has been demonstrated in prior trials with pocket gophers (Cummings 1962). Miller (1954) demonstrated that fumigants probably were ineffective because the gasses did not effectively penetrate the tunnels, and pocket gophers plugged their burrows isolating themselves from the toxin before a fatal amount was inhaled. These problems may be overcome if a fumigant was not readily detected by the pocket gopher, or if it was more rapidly and extensively dispersed through the system. Aluminum phosphide appears not to be detected by pocket gophers and can be effective to control pocket gophers (Marsh 1992). However, field test revealed limited efficacy of aluminum phosphide to control pocket gopher on forest sites (unpublished data).

We decided to test the possibilities of using gas cartridges in conjunction with a blower system to reduce pocket gopher populations on forest sites. Previous field evaluations with a forced air component indicated that more research is warranted to evaluate the advantages of combining a forced air component with gas cartridges (Marsh 1995). When ignited, gas cartridges emit carbon monoxide and nitrogen gas (Savarie et al. 1980). These components do not persist in the environment and are probably less hazardous than some other fumigants. Marsh (1995) predicted that greater reliance will be placed on the gas cartridge to control rodents as other types of rodenticides became less available.

A series of experiments were conducted to assess the benefits of increasing air flow when using gas cartridges as a tool to reduce pocket gopher activity. First, we monitored the dispersal of carbon monoxide through an artificial burrow system with and without a blower system. We then repeated parts of the first experiment using vacated pocket gopher burrows to monitor the extent and rate of carbon monoxide dispersal under more natural conditions rather than in the artificial system. Subsequently, we conducted field trials using a blower to disperse carbon monoxide to reduce pocket gopher populations on reforestation sites.

EXPERIMENT ONE

The first experiment was conducted to determine the dispersal rate and extent of carbon monoxide when gas cartridges were ignited at the entrance to an artificial burrow system. Dispersal from a single cartridge was compared to gas dispersal from two cartridges burned concurrently or consecutively. Dispersal patterns also were monitored when a modified leaf blower was used to increase air flow through the system. The burrow system was cleaned between each test by blowing fresh air through the system until sensors indicated an absence of carbon monoxide.

Materials and Methods

The simulated burrow system was made from approximately 100 m of clear 5 cm diameter PVC pipe (Figure 1). Elbows and tees were used to create complexity within the system. The artificial system was assembled in three layers with approximately 40 cm between layers, and diagonal pipes connected layers. A pocket gopher, permitted to exercise within the artificial system prior to the test, readily transversed the entire system.

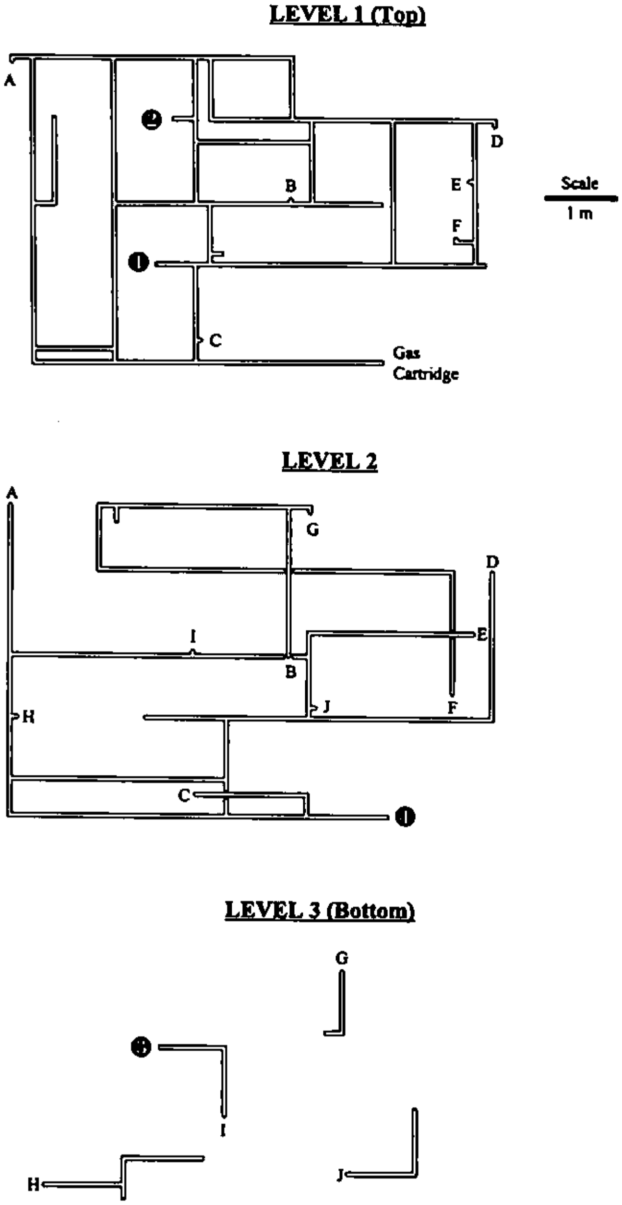


Figure 1. Diagram that depicts the artificial burrow system used in experiment one. The same letter on two different levels are the connecting points between the two levels. The circled numbers are the locations of the sensors to monitor carbon monoxide, which was introduced at the point marked gas cartridge.

Gas cartridges were purchased from the Pocatello Supply Depot (Pocatello, Idaho). The cartridge is an incendiary device which contains sodium nitrate, charcoal, and inert ingredients (Timm 1994, page G-42). Carbon monoxide is the primary emission when ignited. Two hundred parts per million (ppm) of carbon monoxide present in inhaled air may produce symptoms of poisoning in a few hours, and 1,000 ppm can cause unconsciousness in 1 hour and death in 4 hours (Clark 1986).

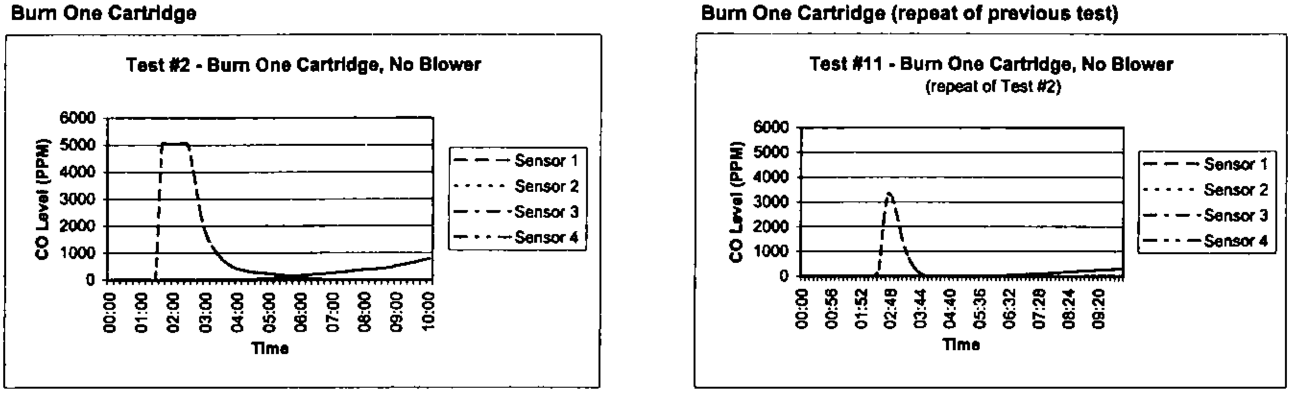
An electric variable-speed leaf blower was placed in-line with the burn box and burrow system for those tests which included forced air. The burn chamber was a metal box with a 5 cm diameter outlet connected to a 5 cm diameter flexible steel hose. This hose was connected directly either to the artificial burrow system or to the leaf blower, which in turn had its own flexible steel hose that connected to the burrow system.

Carbon monoxide sensors (SM95-S1) were purchased from International Sensor Technology (Irvine, California). These sensors had a detection range from 0 to 5,000 ppm. Two sensors were attached to level one (4.5 m and 7.5 m from entrance), and one sensor each was attached to level two (5.5 m from entrance) and to level three (13 m). Figure 1 depicts sensor locations. Distances between the entrance and sensors were measured as the most direct route, however, multiple avenues existed. The sensors were connected to a data logger to collect the carbon monoxide levels every 5 seconds throughout each test.

Test Configurations and Results

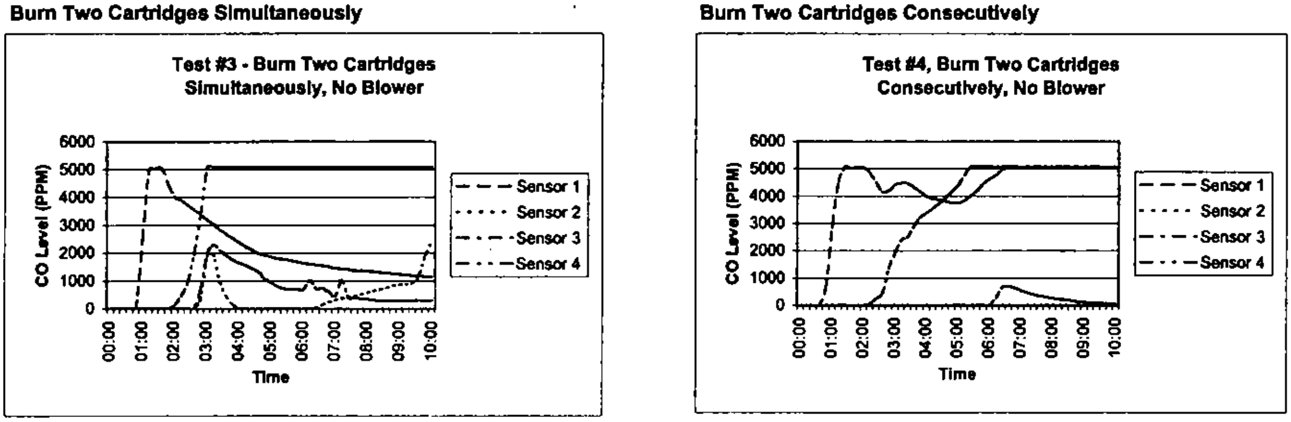
Different burn configurations without a blower. First, we monitored carbon monoxide dispersal when gas cartridges were burned in the burn box without a blower. Three configurations of burning cartridges were tested: 1) burning one cartridge; 2) burning two cartridges concurrently; and 3) burning two cartridges consecutively. During these tests the door to the burn box was sealed once the cartridges ignited and the gas was permitted to passively penetrate the system.

Carbon monoxide did not readily disperse in these tests (Figure 2). The sensor closest to the entrance detected high concentrations regardless of the burn configuration. However, the concentration levels dropped within a couple of minutes in tests with a single cartridge, and low concentrations or no carbon monoxide was detected by the other sensors. Gas dispersal appeared greatest when two cartridges were burned concurrently. High concentrations of carbon monoxide persisted the longest at the two sensors nearest the entrance when two cartridges were burned consecutively, but negligible concentrations were detected by the more distant sensors.



Burn One Cartridge

Burn One Cartridge (repeat of previous test)



Burn Two Cartridges Simultaneously

Burn Two Cartridges Consecutively

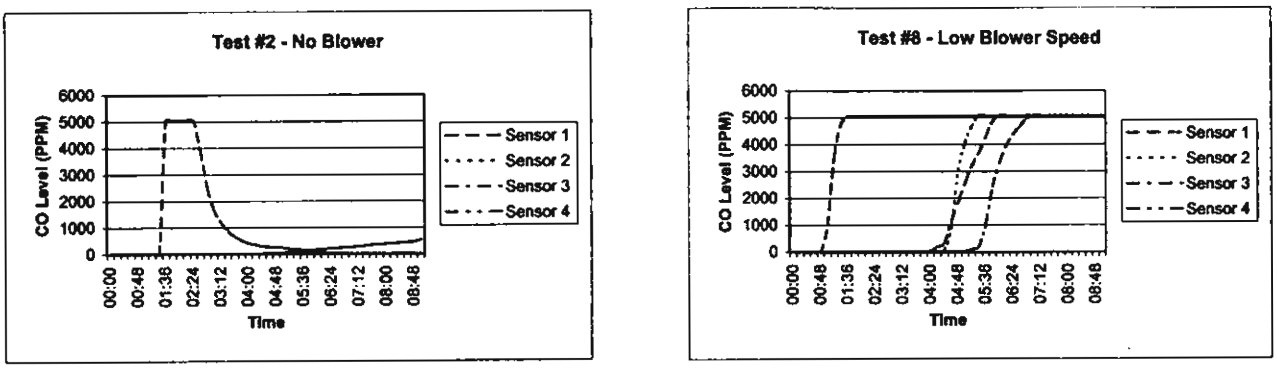
Figure 2. Carbon monoxide concentrations over time at each sensor when cartridges were burned without a blower. The three burn configurations were: 1) burn one cartridge; 2) burn two cartridges concurrently; and 3) burn two cartridges consecutively.

Single cartridge with different blower speeds. Next, we determined the effects of different blower speeds on the distribution pattern of carbon monoxide. For these tests, we burned a single cartridge and used different blower flow rates to distribute the gas. Blower speeds were low, medium (half-way between low and high), and high. Actual rate of air flow (meters per second) was not measured, but these rough categories indicated a rough estimate on how rates of air flow impact gas dispersal. The blower was activated only during the period when the cartridge was actually burning, approximately 6 minutes.

The blower significantly increased the dispersal of carbon monoxide through the system (Figure 3). All sensors detected carbon monoxide concentrations of 5,000 ppm within 5.5 minutes after igniting the cartridge in the test using a blower set at the low rate. Further, these high concentrations were maintained until the test was halted after 9 minutes. Gas dispersal was more rapid with the blower set on medium, all sensors indicated 5,000 ppm within 2.5 minutes. However, within 4 minutes the gas concentration was already beginning to decline at the closest sensor. Dispersal was even more rapid at the high speed, but a subsequent concentration decline also occurred quickly.

No Blower

Blower on Low



Blower on Medium

Blower on High

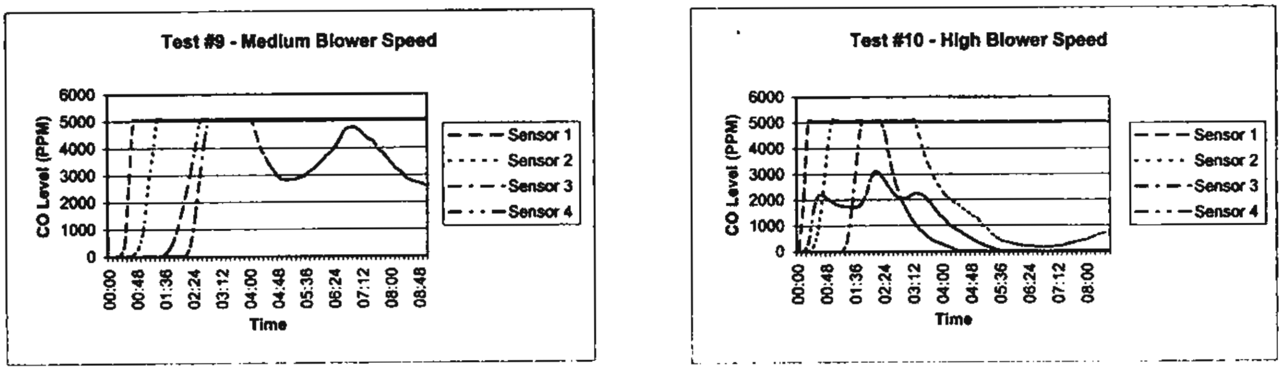


Figure 3. Carbon monoxide concentrations over time at each sensor when a single cartridge was burned with no blower, or while a blower was used at low, medium, or high speeds.

Different burn configuration with blower. These tests repeated the different burn configurations (one cartridge, two cartridges concurrently, two cartridges consecutively) with the blower set at the low air flow rate. Results of these tests indicated that the most rapid and persistent dispersal was achieved by burning two cartridges simultaneously (Figure 4).

Different blower rates for different durations. These tests assessed whether it was more effective to run the blower only during the burn phase or to continue running the blower after the cartridges had expired. Two cartridges were burned concurrently in each of these tests. Gas dispersal was monitored using the three different blower rates, running the blower for either 6 minutes (time for cartridges to burn) or for approximately 20 minutes. Results of these tests demonstrated that the carbon monoxide quickly dissipated when the blower ran for longer than 6 minutes (Figure 5). Running the blower beyond the burn life of the cartridge, only served to introduce fresh air into the system, reducing the concentration levels of carbon monoxide.

EXPERIMENT TWO

The first experiment demonstrated that the best carbon monoxide dispersal occurred when two cartridges were burned concurrently and the blower was set at a low rate. Dispersal was poor without a blower and though the gas dispersed more rapidly at the higher air flow rates, high concentrations deteriorated quickly. The second experiment was conducted to determine whether similar results occurred under more natural conditions.

Materials and Methods

A previous test had required transmitter-fixed pocket gophers to be individually penned in 3 x 5 m pens with 75 cm of soil (Nolte and Wagner 1999). These animals had been allowed two months to establish nests and burrow systems prior to their removal. Several animals were removed from their nests and these nests were marked for later use in this experiment. No animals remained in the pens at the time of the test.

Experiment two was similar to experiment one except pocket gopher created burrows were treated instead of the artificial burrow system. Gas cartridges, blower system, burn chamber, and monitoring devices were the same as described for experiment one. The monitoring device was placed in the nest and readings were taken every 5 seconds during each test. The flexible steel hose from either the blower or the burn chamber, depending on the test, was inserted in an open burrow. Two cartridges were burned concurrently during each test. The difference among tests was the air flow rate created by the blower: none, low, medium and high. The blower was run only while the cartridges were burning, approximately 6 minutes.

Results

The highest concentration of carbon monoxide was attained in the nest when using the blower on the low speed setting. At the low setting the carbon monoxide levels rose quickly peaking at approximately 2,500 ppm, then steadily declined until leveling off around 800 ppm where it remained until the test was halted after 40 minutes. The higher blower rates produced lower carbon monoxide concentrations in the nest than the low rate. These reduced concentrations were probably because the higher blower rates introduced additional fresh air to the system. When no blower was employed, the carbon monoxide concentration level was slow to rise, though it rose erratically throughout the 40 minute test. Regardless of treatment, the gas appeared to settle in the lower portions of the burrow system where it remained until the end of the monitoring period.

EXPERIMENT THREE

Experiments one and two demonstrated that the best rate and extent of carbon monoxide dispersal was achieved by burning two cartridges with a slight increase in air flow. Experiment three assessed the efficacy of this approach to reduce pocket gopher activity when implemented in the field.

Materials and Methods

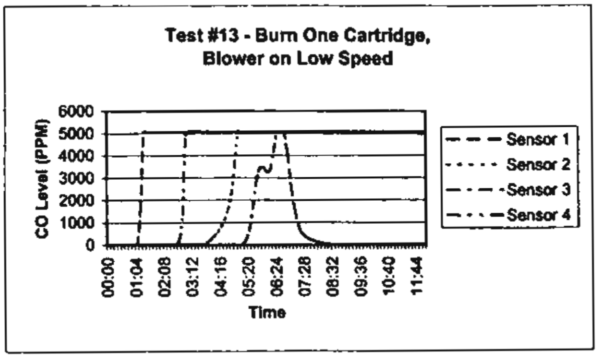
The study was conducted on the Rogue River National Forest in Klamath County approximately 30 km east of Ashland, Oregon. The selected site was an area where past reforestation efforts have been thwarted, at least in part, because of damage to tree seedlings inflicted by pocket gopher. The unit elevation was approximately 1,500 m. Eight blocks consisting of 3 plots (40 x 80 m) were established on the site. A 20 x 20 m grid was laid across each plot to ease mapping of pocket gopher locations. At least 50 m separated treatment plots within a block, and blocks also were at least 50 m apart.

The three treatments incorporated in the study were: 1) a control (no treatment); 2) two gas cartridges per pocket gopher system burned simultaneously without the blower; and 3) two gas cartridges per pocket gopher system burned simultaneously with the blower run at a low speed while the cartridges were burning. Treatments were randomly assigned to 1 of the 3 plots within each block. The gas cartridges were the same as described above. Modified gasoline powered leaf blowers were used in this study rather than the previously used modified electric leaf blower because of the inaccessibility of electricity. Unfortunately, the air flow rate was more difficult to control in the gasoline powered leaf blowers, and when these devices were operated at low speed they produced a faster air flow rate than was considered optimum. The burn boxes operated similarly though they too were modified to further reduce possible fire hazards. The modification consisted of changing the rack for easier removal of spent cartridges to ensure hot debris was not spilt on the ground.

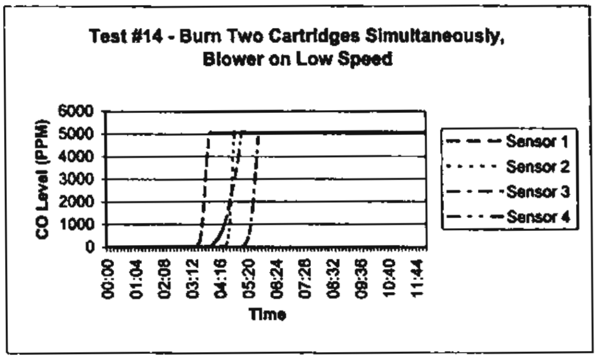
All active pocket gopher systems, indicated by mounds of soil created by pocket gopher, were identified, flagged, and marked on a map prior to the experiment. An open-hole survey conducted within three days prior to treatment indicated current pocket gopher activity. Three holes were opened for each pocket gopher system marked on the map. Active burrows then were confirmed by assessing which systems contained ≥ 1 plugged hole 48 hours after it was opened.

Treatments were applied only to confirmed active burrows. Attempts were made to treat 8 burrow systems within each plot, but lower activity reduced this number

Burn One Cartridge Only



Burn Two Cartridges Simultaneously



Burn Two Cartridges Consecutively

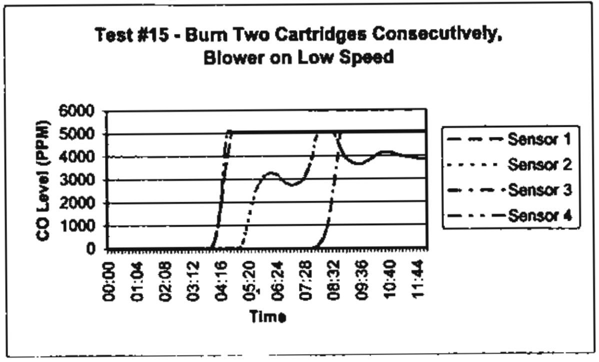
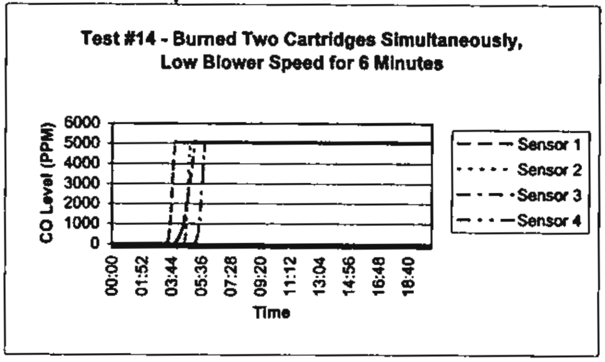
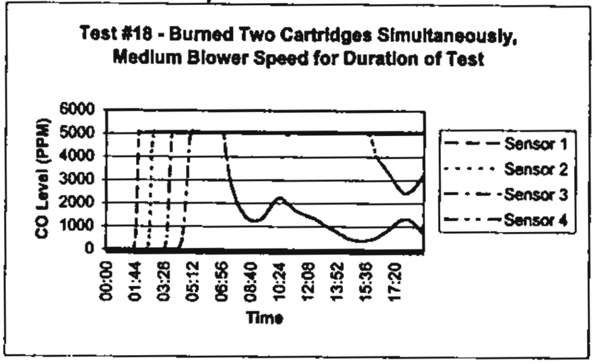


Figure 4. Carbon monoxide concentrations over time at each sensor when the different burn configurations were tested with a blower at a low speed.

Blower on Low Speed for 6 Minutes



Blower on Medium Speed for Entire Test



Blower on High Speed for Entire Test

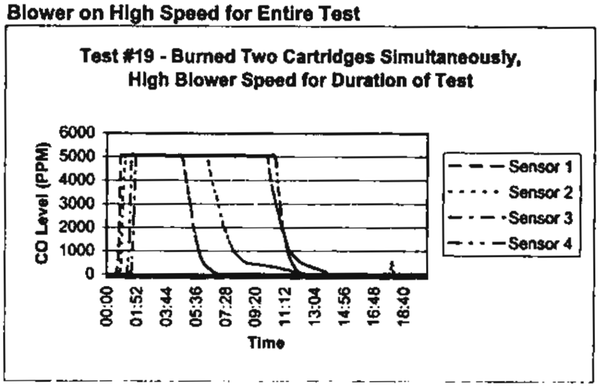


Figure 5. Carbon monoxide concentrations over time at each sensor when the blower was run at a low speed while cartridges burned or when the blower was run at higher speeds (medium and high) beyond the period that the cartrdiges burned.

to 6 on a few plots. Activity post fumigation was assessed by opening 3 holes for each test system the day after treatment. Systems with ≥1 plugged hole 48 hours after it was opened were considered active, while systems where none of the holes had been plugged within 48 hours were considered inactive.

Differences in pocket gopher activity post treatment was assessed in a single factor analysis of variance. The factor was treatment (3-levels) and the dependent variable was the proportion of active systems post treatment relative to the number of treated systems within each plot. Thus, a value of 1 indicated no change in activity while a value of zero indicated that activity had been eliminated.

Results

Pocket gopher activity post treatment was similar across applications ($P > 0.35$). Pocket gopher activity remained high regardless of treatment (Table 1).

Table 1. The total number of active pocket gopher systems before and 48 hours after no fumigation (control), fumigation by burning two gas cartridges (gas), and fumigation by burning two gas cartridges with a blower to enhance gas dispersal (gas/blower).

	Burrow System Activity		
Treatment	Prior	Post	Proportion
Control	60	55	.92
Gas	61	53	.87
Gas/Blower	62	2	.84

DISCUSSION

The first two experiments demonstrated that the dispersal of carbon monoxide emitted by burning gas cartridges could be greatly increased with forced air from a blower system. Dispersal without a blower system was minimal. These tests also demonstrated that high air flow rates or prolonged use of the blower introduced fresh air into the systems reducing carbon monoxide concentrations. Unfortunately, improved dispersal of carbon monoxide did not equate to reduced pocket gopher activity post treatment in the field.

Observations of smoke escaping from beneath the ground indicated the gasses from the cartridges were being rapidly dispersed. On several occasions, smoke was seen emerging from the systems up to 20 m from the injection point within a few minutes after starting the blower. These escape points were quickly closed to contain the fumigant. The air flow rate generated from the gasoline powered leaf blowers may have been a possible problem. The more rapid rate may have introduced fresh air to the systems reducing carbon monoxide concentration below a lethal dose.

Another likely problem was that even with a more rapid dispersal rate, the pocket gophers were still able to detect and plug burrows before being exposed to a lethal dose of carbon monoxide. At present, we are attempting to monitor how fast pocket gopher respond to air flows with and without gasses from burning cartridges. Pocket gophers have been placed in narrow pens (20 cm wide) with glass panels (2 x 5 m) beneath the soil surface. The intent was to monitor pocket gopher responses when gas was injected into their systems. Once we understand what cues were required to initiate a response and how the response was made, we may be able to circumvent this plugging behavior. However, thus far we have not conducted this experiment because of plugs installed by pocket gopher below ground level. Pocket gopher placed in artificial burrows also exhibit plugging throughout their burrow systems. Often these plugs isolate the gophers in their nest. This type of plugging behavior inhibits fumigants from reaching the animals. The frequency of this behavior under natural conditions is unknown, although we speculate it is fairly frequent among pocket gophers we collect for our studies.

The efficacy of aluminum phosphide to control pocket gophers (Marsh 1992) indicates at least some pocket gopher are susceptible to fumigants. Perhaps the efficacy of aluminum phosphide to reduce pocket gopher activity could be further increased if the application was combined with a blower system. It may be possible to convert the burn box used in our studies to a sealed chamber to activate aluminum phosphide tablets. Additional control over the release and dispersal of phosphine gas may make aluminum phosphide applications more feasible for use on reforestation sites. Our tests also may have applicability in improving techniques to fumigate other species (e.g., ground squirrels), particularly those species that are less likely to plug their tunnels.

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