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Investigations of methods to reduce damage by voles

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Abstract: Voles {*Microtus* spp.), small burrowing rodents, range over much of North America. Populations cycle and achieve peak densities every 3-5 years. This can result in severe damage to various resources: orchards, forest plantings, alfalfa and other crops, ornamentals, lawns, and gardens. A variety of methods are used to reduce vole damage, but there is still a need for new, cost-effective, and environmentally benign approaches. We investigated numerous candidate repellents and barriers with indoor vole colonies in soil-filled tanks. Several compounds (blood meal, capsaicin, castor oil, coyote urine, quebracho, and thiram) showed promise as repellents, but only at high concentrations. Many other compounds were completely ineffective. Voles breached short physical barriers, either by climbing or burrowing. Taller barriers were less often breached by voles. Adding a repellent, coyote urine, inside the barrier increased barrier effectiveness. A tactile barrier, sand in acrylic paint, did not reduce vole gnawing hybrid poplar sticks. While some of these approaches appeared promising, field testing will be needed to determine the cost, effectiveness, and duration of protection under more natural conditions. Our findings are discussed within the context of an integrated pest management strategy to reduce damage by voles more effectively.

Key words: barriers, IPM, *Microtus,* repellents, voles, wildlife damage

Voles can cause severe damage to agricultural crops, orchards, and reforestation efforts (Lewis and O'Brien 1990, O'Brien 1994, Tertil 1977). Damage is likely to be significant when populations achieve densities > 200/ha (Johnson 1958, Babinska-Werka 1979). The traditional method to reduce vole densities is the use of toxicants (zinc phosphide or anticoagulants) broadcast over the infested area or placed in bait stations (O'Brien 1994). There is a growing need for additional, and in particular, nonlethal, methods to reduce damage by voles because of reduced availability of toxicants and socio-political pressures.

Although capsaicin and thiram are registered vole repellents, their effectiveness has been questioned (O'Brien 1994). They were included in the present study to provide an additional evaluation of their effectiveness and to compare them as "standards" against other potential vole repellents. Previous studies suggest that predator odors (Sullivan et al. 1988), some plant extracts (Nolte et al. 1995, Wager-Page et al. 1997), and cohort odors (Salmon and Marsh 1989, Ferkin and Zucker 1991), have the potential to influence vole population dynamics, densities, and activities. Additionally, barriers, especially in combination with repellents or traps (Yang et al. 1970), have the potential to reduce vole reinvasion and subsequent damage (Davies and Pepper 1989, Marsh et al. 1990, Singleton et al. 1999). While researchers have rarely investigated combinations of methods, successful management of populations and damage probably requires use of multiple methods (Askham 1992, Witmer et al. 2000). New chemicals or barrier devices could become part of an integrated pest management (IPM) strategy to reduce vole damage with decreased reliance on lethal methods (Askham 1992, Witmer et al. 1995).

The objective of this study was to investigate chemical compounds and physical barriers that could alter movements, activities, and feeding by voles in order to reduce agricultural damage. We hypothesized that voles exposed to selected chemicals or barriers would respond differently as reflected by their movements, activities, and feeding when compared to voles exposed to placebos or carriers.

Methods

The prairie voles {*Microtus ochrogaster)* used in this study were live-trapped from various sites in north-central Colorado. Trials were conducted using twelve 2-m diameter metal livestock watering tanks, each containing about 25 cm of topsoil suitable for burrowing. The tanks were placed in a simulated natural environment room of the National Wildlife Research Center's Animal Research Building. Four voles, trapped from the same vicinity, were placed in each tank and allowed 2 weeks to acclimate to the new surroundings and to establish burrows. This helped to maintain social compatibility between the voles and better establish social hierarchies.

The voles in each tank were provided with rat chow and water, *ad libitum,* in a central, open sided, clear plastic feeding/watering station. Several small chunks of fresh apple were placed daily on the soil surface of each tank. A handful of straw was added as needed to provide cover and to be used as nesting material in burrows. Periodically (about once per week), the soil in each tank was watered to maintain a favorable soil moisture regime. A 12-hour light, 12-hour dark cycle was maintained in the room.

The voles established breeding colonies in each soil tank. At about 6-week intervals, to check on the health of the voles and to keep the tanks from becoming too crowded, the voles in each tank were live-trapped, examined briefly for physical condition, and 4 were returned to each tank. Additional voles that resulted from reproduction were used, as needed, in other tanks, or for other studies, or were euthanized. Unhealthy animals were euthanized.

Repellent trials

At the start of a repellent trial, the 6 tanks on 1 side of the room were randomly assigned as control tanks; the other 6 tanks became treatment tanks. In the treatment tanks, a test material was applied to 5 apple chunks (cubes about 2 cm on a side) skewered on a wooden stick. The stick was inserted into the soil of a tank in a vertical position with the lowest apple chunk just touching the soil surface. The materials tested are listed in Table 1. The control tanks received a skewer stick with 5 untreated apple chunks. All chunks were weighed before and after the trial. The number of chunks damaged or removed was also monitored. Chunks were often taken below ground, so actual onsumption was not measured. On trial days, the voles still had rat chow and water available, but the daily apple chunks were not placed on the soil; only those on the wooden stick were available. Three sticks each of skewered treated and untreated apple chunks were placed in a soil tank containing no voles to monitor moisture loss. In most cases, apple chunks were retrieved and processed 24 hours after placement in the tanks. However, in some cases, when little damage occurred to the apple chunks, the trial was extended up to 96 hours to test the duration of repellency. At least 3 days of routine animal maintenance of all tanks occurred between trials. A 1-way ANOVA was used to determine whether or not any of the test materials were significantly ($P \leq 0.05$) effective in preventing vole damage. When significant differences were detected, Duncan's Multiple Range Test was used to compare treatment means.

Barrier trials

Physical barrier trials were conducted with a procedure similar to the repellent trials procedure. However, instead of a chemical compound, a physical barrier of plastic, metal, or wire mesh was placed around the skewered stick of untreated apple chunks in the treatment tanks. The control tanks had unprotected skewered sticks of untreated apple chunks. In 1 trial, a small, plastic weighing dish containing a paper towel soaked in coyote urine was placed within the barrier and next to the skewer stick. A plastic barrier that had been ineffective in protecting the apple chunks was used to test the combination of a barrier and the coyote urine repellent. The types of barriers tested are described in Table 2. A 1-way ANOVA was used to determine whether or not any of the test barriers were significantly ($P \leq 0.05$) effective in preventing vole damage. When significant differences were detected, Duncan's Multiple Range Test was sued to compare treatment means.

The tactile barrier trial used hybrid poplar sticks (each 25 cm long and about 1.5 cm in diameter). One stick, treated or untreated, was randomly assigned to each soil tank. The untreated sticks were coated with an acrylic paint, the "carrier" material. The treated sticks were coated with the acrylic paint which had been mixed 1:1 with an abrasive, fine sand material (the material used on non-skid floor surfaces; grit size of 16-100). The percent of surface area gnawed by voles was determined for each stick after 72 hours exposure. The percent of surface damage on treated and untreated sticks was compared using a t-test.

Results and discussion

Several of the tested materials provided significant ($P < 0.001$) repellency of voles to treated apple chunks, including blood meal, coyote urine, quebracho, and thiram (Table 1). Capsaicin showed a marginal repellency, but 0.5% was the highest concentration used in these trials. Other researchers have found that concentrations of $\geq 1\%$ are needed to repel some rodent species (S. Shumake, personal communication). Most of the tested materials, however, did not repel voles from the apple chunks. No materials gave complete protection and when 96-hour trials were conducted, the test results suggested that repellency might be short-lived, except for thiram. Additionally, high concentrations were required to achieve effectiveness: lower concentrations of castor oil were not effective as repellents (Table 1).

Table 1. Average number of apple chunks removed by voles (and the standard deviation) with 5 chunks offered per 6 treatment soil tanks when apples were coated with various candidate repellents. Trials were for a 24-hour period unless otherwise indicated. In all cases with the 6 control (5 untreated apple chunks offered per tank) soil tanks, all apple chunks were consumed.

A. Materials Showing Little Repellency:

Material	Mean No. Chunks Removed (S.D.)	Material	Mean No. Chunks Removed (S.D.)
Denatonium benzoate (0.2%)	5(0)	Garlic oil (100%)	5(0)
Denatonium saccharide (0.065%)	4.9 (0.2)	Spearmint oil (10%)	5(0)
Parachlorobenzene (15%)	5(0)	Almond oil (100%)	5(0)
Methyl nonyl ketone (2%)	5(0)	Castor oil (0.65%)	5(0)
Egg solids (94%)	5(0)	Castor oil (16%)	4.8 (0.4)
Putrescent eggs (37%)	5(0)	Selenium (400 ppm)	4.5(1.2)
Ammonium salts of higher fatty acids (15%)	5(0)	Thymoil (2.5%), peppermint oil (2.5%) white pepper (5%)	4.4(1.4)

B. Materials Showing Some Repellency:

Material	Mean No. Chunks Removed (S.D.)	Material	Mean No. Chunks Removed (S.D.)
Capsaicin (0.25%)	3.3(1.9)	Capsaicin (0.5%)	3.7(2.1)
Blood meal (24 hrs) (100%)	2.8 (2.5)*	Blood meal (96 hrs) (100%)	4.2 (2.0)
Thiram (24 hrs) (21%)	2.7 (2.0)*	Thiram (96 hrs) (21%)	0.75 (0.76)*
Quebracho (24 hrs) (100%)	2.8 (1.8)*	Quebracho (96 hrs) (100%)	3.5 (2.0)
Coyote urine (24 hrs) (100%)	2.2 (2.3)*	Coyote urine (96 hrs) (100%)	3.3 (2.6)
Castor oil (100%)	2.8 (2.5)*		

*P<0.001

Table 2. Average number of apple chunks removed by voles (and the standard deviation) with 5 chunks offered per 6 treatment soil tanks when apple chunks were surrounded by various candidate barriers. Trials were for a 24-hour period. In all cases with the 6 control (5 untreated apple chunks offered per tank) soil tanks, all apple chunks were consumed.

Barrier Material	Mean No. Chunks Removed (S.D.)
Solid metal, 15 cm tall	5(0)
Solid plastic, 15 cm tall	5(0)
Wire mesh (13 mm squares), 25 cm tall	1.7(2.6)*
Plastic with 13 mm diameter holes, 30 cm tall	2.5 (2.7)*
Solid plastic, 15 cm tall containing pan with coyote urine	2.9 (2.5)
Tactile barrier	Mean % Surface Damage (S.D.)
Hybrid poplar sticks, 25 cm long with 1.5 cm diameter, coated with acrylic paint (control)	28.6(12.7)
Hybrid poplar sticks, 25 cm long with 1.5 cm diameter, coated with acrylic paint containing fine sand (16-100 grit size)	25.3 (23.0)

*P<0.007

Effective repellents usually work through 1 of 3 mechanisms: eliciting pain, causing illness, or provoking fear (Mason 1998). The 0.25% and 0.5% capsaicin treatments caused pain to the trigeminal nerves upon contact. The 21% thiram probably caused illness upon consumption. This may explain why the apple chunk removal decreased from the 24-hour to the 96-hour period (Table 1). Nolte and Barnett (2000) also found capsaicin and thiram coatings to reduce seed depredation by mice. The undiluted coyote urine probably caused a fear response in that the voles perceived that a predator may have been present. Swihart et al. (1997) also reported that predator urines had a repellency effect on woodchucks and voles. Another effective repellent, 100% castor oil, may have evoked repellency because of its highly viscous nature. The diluted castor oil (0.65% and 16%) did not elicit repellency.

Although some researchers have suggested that some plant oil extracts, such as mint oils, may show repellency, we did not find this to be the case for voles with the oils (almond, garlic, spearmint) that we tested. On the other hand, Wager-Page et al. (1997) found Siberian pine needle oil to be an effective repellent of voles under some conditions. Additionally, several bitter compounds (denatonium benzoate and denatonium saccharide) did not show repellency, although quebracho (a bitter, dried plant material) did. Other researchers have reported that, while bitter compounds may be repellent to some omnivores (humans, bears), they are generally not repellent to strict herbivores (Nolte et al. 1994).

It was a little surprising that egg solids and fermented eggs were not repellent to voles. These materials are used in several commercial animal repellents and are considered to be fairly repellent, especially to ungulates (Nolte 1998,Witmer et al.1997). It is thought that the sulfurous odors of protein breakdown in these materials evoke a fear response similar to that of coyote urine. Several other materials with strong, noxious odors (ammonium salts of higher fatty acids, methyl nonyl ketone, and paradichlorobenzene) did not seem to show repellency.

Some earlier wildlife repellent studies (Rediske and Lawrence 1962, Allan et al. 1983) suggested that selenium could be used effectively as a wildlife repellent. In our trial, a fairly high concentration of selenium (400 ppm), topically applied, did not prevent voles from removing apple chunks. This is similar to the findings of 1 of us (B. Moser, unpublished data), evaluating vole repellency after selenium uptake in hybrid poplars. Additionally, high tissue concentrations of selenium (often less than 100 ppm) in some plant species can be phytotoxic (Allan et al. 1983). Much higher concentrations may be required as an effective topical repellent (Rediske and Lawrence 1962).

Short (15 cm) physical barriers were not protective ($P>0.05$) of the apple chunks (Table 2). The voles would climb over the barrier or dig under it. The 25- and 30-cm-tall barriers provided significant ($P<0.007$) protection to the untreated apple chunks (Table 2). Given more time, the voles would have probably dug under these barriers as the barriers were not buried in the soil. O'Brien (1994) recommended that hardware cloth barriers be buried 6 inches below the soil surface. Plastic mesh barriers around conifer seedlings, both above and below ground, did not always provide protection against foraging pocket gophers (Pipas and Witmer 1999); however, Pauls (1986) reported some protection from foraging voles.

It was interesting that while the 15 cm solid plastic barrier did not protect the apple chunks from voles, the addition of the coyote urine within the barrier reduced apple chunk removal by the voles, although the difference was not significant ($P>0.05$; Table 2). We have not been able to locate any published results in regard to use of combinations of barriers and repellents for wildlife damage reduction; however, Singleton et al. (1999) were able to slow rodent reinvasion of crop areas with a combined use of barriers and traps. Barriers by themselves were not completely able to stop the expansion of prairie dog colonies (Witmer et al. 2000).

Our tactile barrier (sand in acrylic paint) did not result in a significant ($P=0.81$) reduction in hybrid poplar stick gnawing by voles (Table 2). Another researcher (D. Nolte, personal communication) found that some tactile repellents reduced tree bole gnawing by beaver. We only tested 1 tactile repellent in our vole trials, so the negative result is inconclusive for evaluation of this approach to vole damage reduction.

Management implications

It appears that a variety of repellents and barriers could be used to reduce damage by voles. Based on the result of this study with captive voles, however, high concentrations of repellents would be required and barriers would have to be tall (> 25 cm). Field testing is needed to determine the cost, effectiveness, and duration of protection under large-scale, natural settings.

The high reproductive potential of voles, combined with the 3-5 year cycle when peak densities are realized, will make it difficult to control vole populations and damage with nonlethal approaches alone. It is more likely that an integrated pest management strategy, using many techniques, both nonlethal and lethal, will be necessary to keep damage at or below acceptable levels (e.g., Engeman and Witmer 2000b, Ramsey and Wilson 2000, Witmer et al. 2000). Additionally, it is important to monitor pest populations so that intervention can be implemented before serious damage is unavoidable. Efficient, relatively simple methods are needed to assist resource managers and landowners in this important task (e.g., Engeman and Witmer 2000a). Decision keys are also needed to make decisions regarding choice of methods and timing of applications (e.g., Binns et al. 2000).

Other methods and tools to reduce rodent damage should be investigated. Research is underway with habitat management (G. Witmer, unpublished data), the use of endophytic grasses (G. Witmer, unpublished data), natural plant extracts (Nolte et al. 1995), combinations of repellents (Nolte and Barnett 2000), and fertility control (P. Nash, unpublished data). Additionally, much data has been recently submitted to the U.S. Environmental Protection Agency to maintain rodenticide registrations (K. Fagerstone, personal communication). Indeed, a variety of approaches, integrated into an ecological-based framework, is needed to successfully manage prolific and adaptable rodent populations (Singleton et al. 1999, Way et al. 2000).

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