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ABSTRACT: Commercial orchards, ornamental nurseries, and residential horticulture in North Carolina experience economic losses due to pine vole (*Microtus pinetorum*) depredation. Predator odors and the herbicide Casoron were tested as potential repellents for pine voles. To test for avoidance behavior, animals were allowed to build a nest in one of two chambers attached to each arm of a Y-maze. The cage containing the nest was treated with either a test repellent compound, methylene chloride (solvent control), or left unmanipulated (control). Animals were categorized as either maintaining or changing nest cage preference between pre-test and test periods. The number of animals that changed cage preference in the control group was compared to the treatment groups. Only the Casoron treatments were significantly different, with approximately 50% of the animals changing preference. The difference in time spent in the nest cage during the pre-test and test periods for the treatment groups were compared to control groups. The Casoron and DTT treatments resulted in significant time differences. These results indicate that Casoron has repellent potential and warrants further investigation into its effectiveness in the field. The predator odors tested showed little promise as repellents.

Key words: Repellent, pine vole, *Microtus pinetorum*, North Carolina, orchard

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Each year the commercial orchards, ornamental nurseries and residential horticulture of North Carolina experience significant economic losses due to pine vole (*Microtus pinetorum*) depredation. Problems in apple orchards have received the most attention. Approximately 50% of the tree death within apple orchards is attributed to vole damage, resulting in an estimated annual loss of $2.5 million (Bromley et al. 1992). Damage in apple orchards occurs when pine voles feed on the roots and the sub-surface portion of the trunk of trees (Byer 1976).

Recent advances in the field of inter-specific chemical communication suggest that predator odors can be used as repellents of pest species (Schumake 1977). Sullivan et al. (1988) isolated the most volatile components of several predator odors and tested these compounds for their repellent potential. Traps treated with a red fox (*Vulpes fulva*) fecal component, 2,5-dihydro-2,4,5,-trimethylthizoline (DTT), caught significantly fewer Montane voles (*M. montanus*). Treatment with a mixture of 2-*n*-propylthietane and 3-*n*-propyl-1,2-dithiolane (stoat, *Mustela* spp., anal gland component) also reduced the number of voles trapped. These treatments also significantly reduced the number of apple trees that were damaged.

This preliminary report describes tests of 2-*n*-propylthietane and DTT to induce avoidance behavior in pine voles. In addition, anecdotal observations by horticulturists indicate that orchardists using the herbicide Casoron to control weeds have fewer vole problems. Casoron (Dichlobenil, Uniroyal) 4G and 10G (4% and 10% active ingredients) was also tested for its repellent potential. A more detailed report on the effectiveness of Casoron is in preparation.

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METHODS

Wild stock, laboratory reared pine voles were weaned at approximately 28 days of age and housed individually for 3 weeks prior to testing. Animals were tested when 5 to 12 months old and had no prior experience with the apparatus. Each vole was tested only once. Y-maze apparatuses fitted with infrared sensors to monitor movements were used.

Voles were allowed to establish a nest in one arm of the Y-maze for 24 hrs. The animal was returned to the holding chamber and the location of its nest was recorded. The cage containing the nest was then either treated with a potential repellent compound, or treated as a control. The animal was given access to the Y-tube for an additional 6 hours and its position within the apparatus was recorded. The duration of time in minutes spent in the cages and the stem of the Y-tube was determined using the event recorder printout. In addition, trials were taped using a time-lapse video recorder. The tapes were used to determine the position of the voles when the event recorder printout was inconclusive. After every trial, the apparatuses were cleaned with a 50% alcohol in water solution. The bedding, nest material and food were discarded and replaced with fresh material.

For each trial, cage preference was determined during the pre-test and test periods. Cage preference was categorized using two criteria: (1) the presence of a nest in a cage and at least 50% of the time spent in that nest cage during the pretest period or (2) the presence of a nest **or** 60% of the time spent in a cage or the stem during the test period. The differences in time spent in the nest cage between the pretest and the test periods was also recorded for each trial. These differences were analyzed using a Mann-Whitney test.

RESULTS

Chi-square analysis comparing the Control 1 and the solvent treatment did not differ (chi-square = 0.32, p = 0.57, df = 1; Table 1), so these values were pooled as a control group. Neither stoat odor nor fox feces odor (DTT) caused significant changes in preference (stoat: chi-square = 0.24, P = 0.62 fox: chi-square = 1.17, P = 0.28), but the percentage of voles that changed preference when subjected to DTT suggests that more extensive testing might show a statistically significant effect for this treatment. Casoron 4G treatment caused significant changes in cage preference (chi-square = 9.14, P = 0.0025). Control 1 and control 2 treatments did not differ (chi-square = 0.046, P = 0.83) so these values were pooled and compared to the Casoron 10G treatment. The Casoron 10G caused a significant change in cage preference (chi-square 6.99, P 0.008).

Measurements of the mean difference in time spent in the nest cage during the pre-test and test periods showed that the control 1 and solvent treatments did not differ Mann-Whitney test-Z = -0.28 P = 0.78), so these values were pooled as a control group. The stoat odor differences were not significantly different from the control group (p = 0.53), which concurs with the chi-square analysis. The difference in time spent in the nest cage for the Casoron 4G and 10G treatments was significantly different from the control (p = 0.068 and P = 0.027 respectively), which also concurs with the analysis of change in cage preference for this treatment. DTT significantly affected the difference in time spent in the nest cage (P = 0.025). This result does not agree with the analysis of change in cage preference for this treatment.

Table 1. The percentage of animals that changed cage preference between the pre-test and test periods in each treatment.

Treatment	n	% Changed
Control 1	19	5.3
Control 2	15	13.3
Solvent	15	6.7
Casoron 4G	12	50.0
Casoron 10G	15	46.7
Stoat Odor	14	7.1
Fox Odor	14	21.4

DISCUSSION

Of the four compounds tested, only Casoron was found to induce avoidance behavior. 2-Propylthietane did not appear to repel pine voles or effect their behavior. The fox odor (DTT) did not result in a significant number of voles changing cage preference, but it did effect the voles' behavior. The time differences for nest occupation for the fox odor were significantly less than for the control treatments. This indicates that the voles behaved differently when the fox odor was present. DTT produces a stress response in laboratory raised albino rats, as measured by behavioral and biochemical assays (Vernet-Maury et al. 1984). The pine vole's response to DTT exposure within the Y-tube suggests that pine voles, like rats, detect the fox odor. Unfortunately, the DTT does not appear to induce an avoidance response in pine voles, but it may alter behavior In a way that would be useful for vole management. By using DTT to manipulate the stress response of voles, it may be possible to disrupt feeding or reproductive behavior and indirectly result in smaller vole populations. Further experiments determine how fox odor affects vole behavior need to be conducted.

The results indicated that Casoron 4G and 10G have promising repellent potential. Both treatments repelled approximately 50% of the voles from their nest cages. The fact that only some of the voles were repelled may be due to two aspects of the experimental design. First, the stress and anxiety of being tested in a strange, "unnatural" environment may have overridden the repellent effects of Casoron for some animals. Second, a very conservative bioassay was used to indicate repelled behavior. The experiment was designed to determine whether a vole could be prevented from re-entering a nest cage. Casoron's ability to force 50% of the animals to give up the security of their nests, where all the food cubes were often cached, provides strong evidence for its repellent potential.

If Casoron proves to be an effective repellent it would be a very useful and environmentally safe vole control too. Using Casoron as a repellent could reduce the quantity of rodenticides used and frequency of applications. Problems with secondary poisoning of non-target species and development of rodenticide resistant vole population could be reduced because of fewer rodenticide applications. Since Casoron has a low toxicity (oral toxicity: LD50 in rats is > 3.2 g/kg), there would not be any serious threat to non-target species. From a practical perspective, may orchardists are already familiar with Casoron and would likely be receptive to learning new applications for an existing chemical to repel voles. In addition, herbicides are already part of the integrated pest management program in orchards so Casoron application could control weeds as well as repel pine voles.

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