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This paper will outline some of the research related to pine and meadow vole damage control which is currently underway at the Winchester Fruit Research Laboratory and outline some of the areas which we will be pursuing in the future. One question which must be answered whenever a chemical is used to control a pest organism is how that chemical is impacting non-target organisms. A study was initiated in the fall of 1979, with the objective of determining by use of radiotelemetry the fates of birds of prey in the vicinity of orchards treated with Brodifacoum, an anticoagulant rodenticide. A further objective was to indirectly assess secondary hazard to birds of prey and scavengers by collecting live voles and vole carcasses after treatment for analysis for anticoagulant residue.

The study area was an orchard near Front Royal, Virginia. The orchard was located in a heavily wooded area which was known to be inhabited by screech owls (Otus asio), great horned owls (Bubo virginianus), and barred owls (Strix varia). Several species of hawks were also observed in the vicinity of the orchard. The orchard itself supported a heavy population of meadow voles (Microtus pennsylvanicus) which was causing considerable damage to the orchard. The orchard was treated with a broadcast application of 50 ppm Brodifacoum bait.

The screech owl was chosen as a subject for study because of its relative abundance in the area and its non-migratory habits. Two screech owls were mist netted in the orchard, fitted with radio-transmitters and released. Unfortunately, the longest time which any of the screech owls retained its transmitter was 3 days and no data could be collected on the ultimate fates of the owls after orchard treatment with Brodifacoum. Three red-tailed hawks (Buteo jamaicensis) were also captured and two of these were radio-tagged and released. Both birds remained in the vicinity for 2 to 3 weeks after capture but eventually contact ceased and, presumably, the birds had left the area.

In addition to the work with raptors an attempt was made to quantify the numbers of meadow voles which died on the ground surface and the Brodifacoum burdens which they carried as well as the burdens carried by live voles during the latency period between application of the material and the start of vole deaths. This is the period during which birds of prey would be most likely to obtain a secondary exposure to the compound. The analysis of the voles collected has not been completed at this time.

We plan to continue to work with and refine our radio-telemetry techniques in preparation for a similar study next fall. We have begun a program of placing nest boxes suitable for screech owls around various orchards in hopes of attracting screech owls to the area thus giving us subjects for study and, hopefully, an easy means by which to capture the owls when the time comes.

We have also begun a series of laboratory trials concerning the efficacy of some of the various zinc phosphide (Zn_3P_2) preparations presently available for the control of pine and meadow voles in orchards. Zinc phosphide is a compound which has been in use for a number of years and we feel has the potential to be an important part of the total control program available to the grower at the present time. Firstly, since the compound is not a new one, most growers will be familiar with its use; secondly, having a poison which the grower can alternately use which has a mode of action different from that of the anticoagulants presently in use will forestall or possibly prevent the development of vole strains which are resistant to these poisons; thirdly, we have found some of the new preparations of zinc phosphide now available to be very effective.

Not all the zinc phosphide preparations are equally effective, however. Table 1 shows some of the data available at present concerning the efficacy of a 2% zinc phosphide pellet (Bell Labs, Madison, WI) and a 2% zinc phosphide cracked corn-oat preparation (FMC) for meadow voles. The data are from a 3-day choice test designed after the Microtus dry bait efficacy test of Byers and Palmateer (1979) only fresh Golden Delicious apple was substituted for the EPA challenge diet. We feel this substitution makes the test more stringent and makes the competition which the bait faces more of an approximation to that which would be present in the field at times when the bait would be applied. The animals were observed for 5 days after the poison was withdrawn.

The mortality achieved by the pellet was far superior to that of the FMC grain ($X^2_{(1)} = 15.0$; $p<.05$). The Bell Labs material achieved a quicker and more complete kill than the grain bait. The two baits were equally acceptable to the meadow voles, however, in terms of amounts of each bait eaten and the numbers of voles which consumed the bait. The real difference between the two was in the lethality of the baits to those voles which consumed them. Ninety-four percent of the voles consuming the Bell Labs pellet died compared to only 30% of the voles consuming the FMC grain. This difference may be related to the uniformity of the coating of zinc phosphide on the grain. It may be possible for the voles to select grains which do not have an adequate coating and consume only enough bait to develop an aversion to the bait but not a lethal dose. The consumption of the baits dropped to essentially zero by the second day of treatment.

In a 1-day test with no challenge offered (only bait was present in the cage) the performance of the Bell Labs pellet improved to 100% mortality with meadow voles and the FMC bait performance improved to 75%. The time to death was still significantly greater for the FMC bait, however ($p<.05$).

In Table 2 are the results of a 3-day choice trial with pine voles involving the Bell Labs pellet and FMC grain plus two preparations manufactured by the Bonide Chemical Co. (Yorkville, NY) and a 1% paraffin base pellet (ParaZinc) produced by the ArChem Corp. (Portsmouth, OH). One of the Bonide preparations was a zinc phosphide coated cracked corn and the other was whole crushed oats. Both were 2% zinc phosphide.

The Bell Labs pellet did not perform as well with pine voles as it did with meadow voles (80 vs 90% mortality) but did cause significantly more mortality in pine voles ($p<.05$) than all the other preparations except the Bonide corn bait. A Chi-square test for independence comparing the Bonide corn and oats, the FMC grain, and Para Zinc showed no significant relationship between these preparations and the mortality which occurred in the groups of voles fed each ($X^2_{(3)} = 3.60$; $p<.10$). There was also a significant effect of the preparation on the day on which death occurred with the Bell Labs pellet causing mortality in a significantly shorter period of time after the start of exposure than did the two Bonide preparations ($p<.05$).

All the baits were consumed in the same amounts by the pine voles with the exception of the Bonide oats. The low rate of consumption of this preparation by the pine voles may have been an artifact of its low density. Several particles could have been removed from the feeder without resulting in a measurable change in the amount of material originally given to the animal. As was true with meadow voles, the differences in the efficacy of these preparations for pine voles is probably related to the uniformity with which the toxicant is present in the bait.

We plan to continue to test other zinc phosphide materials as they become available to us in order to make this information available to the growers next season. We are also about to undertake studies to examine factors which influence the hoarding response in pine and meadow voles with the objective of improving bait acceptance and movement in the field.

Literature Cited

Byers, R. E., and S. D. Palmateer. 1979 Microtus dry bait laboratory efficacy test method. Pages 101-106 in J. R. Beck (ed.), Vertebrate Pest Control and Management Materials, ASTMSTP 680. American Society for Testing Materials.

Table 1. Performance and acceptability of two zinc phosphide preparations to meadow voles in a 3-day choice test (apple challenge).

	Pellets (Bell Labs)	Grain (FMC)	Control
Mortality	18/20 (90%)	6/20 (30%)	0/20 (0%)
Mean days to death (± SE)[a]	1.3 ± 0.1	2.0 ± 1.1	-
No. consuming bait	18/20 (90%)	20/20 (100%)	-
Mortality in consuming voles	17/18 (94%)	6/20 (30%)	-
Mean bait consumption (± SE)			
Day 1 (n)	0.6 ± 0.1 (20)	0.7 ± 0.1 (20)	-
Day 2 (n)	0.02 ± 0.01 (6)	0.02 ± 0.01 (18)	-
Day 3 (n)	0.0 (3)	0.01 ± 0.01 (15)	-

[a] Significant difference between means ($p<.05$; analysis of variance).

Table 2. Performance and acceptability of five zinc phosphide preparations in a 3-day choice trial with pine voles (apple challenge).

	Control	Bell Labs pellet	Bonide corn	Bonide oats	FMC grain	ParaZinc
Mortality	0/20 (0%)	16/20 (80%)	13/20 (65%)	10/20 (50%)	10/20 (50%)	7/20 (35%)
Mean day of death ($\pm$ SE)	-	1.2 ± 0.1^{a}	$3.2 \pm 0.6^{b,c}$	3.8 ± 0.6^{c}	$1.8 \pm 0.2^{a,b}$	$1.9 \pm 0.5^{a,b}$
No. voles consuming bait	-	19/20 (95%)	19/20 (95%)	4/20 (20%)	16/20 (80%)	18/20 (90%)
No. consumers dying	-	16/19 (84%)	12/19 (63%)	1/4 (25%)	8/16 (50%)	7/18 (39%)
<u>Mean bait consumption</u> ($\pm$ SE)						
Day 1 (n)	-	0.5 ± 0.1^{a} (20)	0.5 ± 0.1^{a} (20)	0.03 ± 0.02^{b} (20)	0.4 ± 0.1^{a} (20)	0.4 ± 0.3^{a} (20)
Day 2 (n)	-	0.0 (8)	0.1 ± 0.03 (16)	0.0 (19)	0.02 ± 0.02 (17)	0.1 ± 0.04 (16)
Day 3 (n)	-	0.0 (4)	0.0 (13)	0.01 ± 0.01 (13)	0.0 (11)	0.0 (15)

[a,b,c] Means in the same row with different superscripts significantly different, $p<.05$ (Duncan's multiple range test).