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ABSTRACT: Hand placed baits of Rozol (Chlorophacinone, CPN), Ramik-Brown (Diphacinone, DPN), and Talon (Brodifacoum, BFC) gave excellent control of pine voles in 1977. Vacor (RH 787) did not give adequate control when a meal preparation was hand placed at 10 lbs/A.

Talon and Rozol broadcast at 25 and 22 lbs/A, respectively, gave 100% and 96% control of pine voles. Five lbs/A of hand placed Talon gave equivalent control. A second broadcast experiment of LM 637, Rozol and Talon at 15 lbs/A each was followed by rain the next day but gave 21%, 66%, and 93% control, respectively.

Ground cover spray of BFC at 5.1 g/ha (or 7.5 g/treated ha) was insufficient for good control and higher rates would be required. A deodorized kerosene formulation of CPN plus a sticker was compared to the Xylene-formulation presently used by the industry for ground cover sprays. Relatively poor control was obtained with both formulations.

INTRODUCTION: The performance of new ground sprays and baits for pine vole control need year to year evaluation under field conditions so that a good understanding of many environmental variables, resistance development, and product quality control will result in more reliable recommendations.

Any damage control method, must meet certain criteria before it can be implemented, such as: 1) economically practical, 2) elimination of damage under most orchard and weather conditions, 3) rapid treatment of large acreages with a minimum of labor power, and equipment, 4) minimum hazard to non-target species, 5) clearance by government agencies if the method is under federal or state control.

Toxic baits and ground sprays have met, to a certain extent, all of the above criteria in the past, and remain the best possible control method for the immediate future. However, any method which would eliminate the need for government clearance will be of great value to the fruit industry.

We have studied rootstock resistance (2) and cultural changes (3) as well as other alternatives to toxic chemicals. Since these methods have not adequately met the first 3 criteria, they will be covered in other papers.

METHODS AND MATERIALS FOR PINE VOLE EXPERIMENTS: Evaluation of pine vole control plots was determined using methods previously described (1,5,6). Randomized complete block designs were used in pine vole experiments which were statistically analyzed. Orchards used for experiments in Table 1, Table 2, Table 3, Table 4, Table 5, and Table 6

had approx. 38, 38, 36, 60, 60, and 80 trees/acre, respectively. All plantings were mature orchards in the vicinity of Winchester, Virginia in the age range of 25-40 years. All experiments utilized 24 sites per plot with 2 sites/tree, except one experiment (Table 6). In this experiment, the 24 sites per plot were established with 1 site/tree.

In addition to pine vole studies, a meadow vole experiment was conducted near Vincennes, Indiana, in a 3-year-old orchard planted 10 ft X 20 ft. The trees were cultivated 2 m wide in a tree line strip the previous spring and summer causing voles to reside in the middles. The orchard block consisted of 48 tree rows crossected by 2 crossroads at 28 tree intervals. Each plot consisted of 7 rows wide (6 middles) X 28 trees long. Twenty four sites were established per plot on top of the soil, about 3 ft from the trunk, adjacent to the cultivated strip and in a meadow vole runway at each of 24 interior trees which were in the center row of each plot. Since the voles might invade adjoining plots in a longitudinal fashion, because of the nature of the cultivated strips, plots were not arranged in a standard experimental design. Rather, plots were arranged so that treatments were joined on the end by the same treatment so that invasions of voles would be a remote possibility. Therefore, plots 1-3; 4-6; 7-9; 10-12; 16-18; 19-20; and 22-23 were treated with the same broadcast treatments (Table 1). Plots 13, 14, and 15 were treated with a single hand placed application of Ramik, Rozol, and Talon, respectively, on November 12. In addition, to identify the species, plot #13 was trapped October 21-26 and 37 meadow voles were caught. By November 3, meadow voles from border rows of plot #13 sufficiently invaded this plot so that it could be treated on November 12.

RESULTS OF PINE VOLE EXPERIMENTS: Hand placement of Ramik-Brown, Rozol, and Talon in a heavy pine vole population gave excellent control (Table 1). The treatments were applied just prior to a misty and light rain period which could have greatly affected control. Baits were placed in runways under shingles and excellent control was achieved. Talon at 5 lbs/A appeared to be the most effective treatment but statistical differences between the 3 materials were not detectable.

In the same orchard, two plots of Vacor 2% meal bait was not adequate to control pine voles (Table 2). Previous experiments with pelletized Vacor also has failed to give adequate control (1,3). However, a number of experiments with a 1% apple cube bait have given outstanding control (1,3,4). I therefore believe that a more acceptable formulation will be required.

Since broadcast treatments of anticoagulant bait may greatly reduce application costs, skilled labor requirements, reduce total treatment time of large acreages, and may reduce hazards to non-target species, Talon and Rozol were applied with a commercial fertilizer spreader to the tree line strip (Table 3). Application rates are expressed as lbs/acre of orchard. Since only 2/3 of the orchard floor was actually treated in these experiments, the rate/treated area (tree line strip) was 50% greater than that listed in the table. Outstanding control was achieved with the broadcast treatments of Talon and Rozol. This orchard had been previously treated with anticoagulants for 3 years and Ramik-Brown in two hand placed applications gave excellent control.

Table 1. Effect of hand placed anticoagulant baits on pine vole activity and population treated Oct. 14, 1977.

Treatment	No. of plots	Rate kg/ha	Rate lbs/A	% Activity[z] Oct 13	Oct 21	Oct 28	Voles/plot (Oct 30-Nov 4)	Voles/ site	% Control
Control	3	--	--	83 a[y]	80 a	72 a	47 a	2.54 a	0
Ramik-Brown 0.005% DPN	3	11.2	10	79 a	27 b	11 b	3 b	0.14 b	94
Rozol 0.005% CPN	3	11.2	10	80 a	23 b	15 b	3 b	0.14 b	94
Talon 0.005% BFC	3	5.6	5	83 a	20 b	1 b	0.3 b	0.01 b	99

[z] Apples placed in 2 holes or runs 5-15 cm below the soil surface on opposite sides of the tree trunk were examined 24 hrs. after placement. Percent activity refers to all sites with vole tooth marks on the apple.

[y] Mean separation, within columns by Duncan's multiple range test, 5%.

Table 2. Effect of Vacor on pine vole activity treated Oct. 21, 1977.

Treatment	No. of plots	Rate kg/ha	Rate lbs/A	% Activity[z] Oct 21	Oct 28	Voles/plot (Oct 30-Nov 4)	Voles/ site	% Control
Control	2	--	--	76	67	40	1.65	0
Vacor 2% RH 787	2	11.2	10	83.5	46	13	0.55	67

[z] Apples placed in 2 holes or runs 5-15 cm below the soil surface on opposite sides of the tree trunk were examined 24 hrs. after placement. Percent activity refers to all sites with vole tooth marks on the apple.

Table 3. Effect of broadcast and hand placed anticoagulants on pine vole activity and populations 1977.

Treatment	No. of plots	Rate kg/ha	Rate lbs/A	Date treated	% Activity[z] Oct 28	% Activity[z] Nov 29	% Activity[z] Dec 2	Voles/plot (Dec 6-13)	Voles/ site	% Control
Control	3	--	--	--	93 a[y]	63 a	72 a	18 a	0.75 a	0
Talon-Hand placed	3	5.6	5	Nov 11	90 a	10 bc	7 bc	1 b	0.04 b	95
Talon-Broadcast	3	28	25	Nov 11	93 a	14 bc	7 bc	0 b	0.00 b	100
Rozol-Broadcast 0.005% CPN	3	26	22	Nov 11	93 a	8 c	0 c	1 b	0.03 b	96
Ramik-Hand placed 0.005% DPN	3	11.2 11.2	10 10	Nov 9 Nov 18	94 a	26 b	15 b	2 b	0.07 b	91

[z] Apples placed in 2 holes or runs 5-15 cm below the soil surface on opposite sides of the tree trunk were examined 24 hrs. after placement. Percent activity refers to all sites with vole tooth marks on the apple.

[y] Mean separation, within columns by Duncan's multiple range test, 5%.

Table 4. Effect of Brodifacoum ground-cover spray on pine vole activity and population treated Nov. 15, 1977.

Treatment	No. of plots	Rate g/ha	% Activity[z] Nov 11	% Activity[z] Dec 2	Voles/plot (Dec 6-13)	Voles/ site	% Control
Control	1	-	96	75	21	0.88	0
BFC	1	1	100	88	31	1.29	-
BFC	1	2.5	100	86	26	1.08	-
BFC	1	5.1	100	63	11	0.46	48

[z] Apples placed in 2 holes or runs 5-15 cm below the soil surface on opposite sides of the tree trunks were examined 24 hrs. after placement. Percent activity refers to all sites with vole tooth marks on the apple.

Ground spray applications of Brodifacoum (BFC) and Chlorophacinone (CPN) were conducted in the same orchard block (Table 4 and 5). Plots used for the Brodifacoum experiment (Table 4) were probably more uniform and heavier in population than in the Chlorophacinone experiment (Table 5). The CPN formulations were applied on November 14 and the BFC on November 15, 1977. Mist and rain occurred November 17 and 18, 1977, and much of the next two weeks were also wet. The BFC at 5.1 g/ha (0.01 lbs/A) was approximately equivalent to CPN at 0.22 g/ha (0.2 lbs/A).

Broadcast treatments of LM 637, Rozol, and Talon were applied December 13, 1977 just before a rainy period on December 14, 1977 (Table 6). Examination of bait in the plots on December 15 indicated that the bait had become very wet and appeared to be unacceptable to the voles. In spite of the severe weather conditions the Talon performed pretty well and the Rozol did not. A wide variation in activity existed between plots with both the Rozol (83%, 83% and 0%) and Talon (42, 0, 8). This great variation is probably related to differences in activity of voles in various sections of the orchard during the first 24 hour period which may have been due to terrain, tunnel system development (surface vs deep), or ground cover differences. In any case, the broadcasting of pelletted bait is probably much more dependent on good weather conditions for vole activity in the upper runway systems, than hand placement in runs and holes. With hand placement, large quantities of bait may be found by the voles and relocated in the first 24 hours. Broadcast baits may not be found as quickly by animals and sufficient quantities must be sought out and accumulated before weathering occurs.

The broadcast bait method has many advantages over hand placement of bait and/or ground cover sprays. Broadcasting of bait is more rapid, requires less costly equipment, less labor, easier calibration and may be less costly.

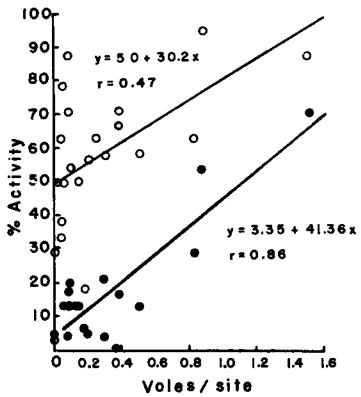

Figure 1. Linear regression of % active sites (○) and highly active sites (●) on voles/site in 23 plots.

Table 5. Effect of Chlorophacinone ground-cover sprays on pine vole activity and populations treated Nov. 14, 1977.

Treatment	No. of plots	Rate kg/ha	Rate lbs/A	% Activity[z] Nov 11	% Activity[z] Dec 2	Voles/plot (Dec 6-13)	Voles/ site	% Control
Control	3	--	--	83 a[y]	68 a	15.3 a	0.64 a	0
CPN-Xylene formulation	3	0.22	0.20	87 a	31 b	4.6 b	0.19 b	70
CPN-Deodorized Kerosene formulation Witco (775) 1/2 pt/100 gal.	3	0.22	0.20	83 a	38 b	7.6 b	0.32 b	50

[z] Apples placed in 2 holes or runs 5-15 cm below the soil surface on opposite sides of the tree trunk were examined 24 hrs. after placement. Percent activity refers to all sites with vole tooth marks on the apple.

[y] Mean separation, within columns by Duncan's multiple range test, 5%.

Table 6. Effect of broadcast anticoagulant baits on pine vole activity treated Dec. 13, 1977.

Treatment[w]	No. of plots	Rate kg/ha	Rate lbs/A	% Activity[z] Dec 2	% Activity[z] Dec 30	Estimated[x] Voles/site	% Control
Control	3	--	--	96 a[y]	88 a	1.65	0
LM 637	3	16.8	15	92 a	79 a	1.30	21
Rozol-CPN	3	16.8	15	92 a	55 ab	0.73	66
Talon-BFC	3	16.8	15	92 a	17 b	0.12	93

[z] Apples placed in 2 holes or runs 5-15 cm below the soil surface on opposite sides of the tree trunk were examined 24 hrs. after placement. Percent activity refers to all sites with vole tooth marks on the apple.

[y] Mean separation, within columns by Duncan's multiple range test, 5%.

[x] Vole population was estimated from regression curve from 1975 and 1976 data (Byers 1978).

[w] Rain occurred on Dec. 14 which caused all baits to deteriorate.

MEADOW VOLE EXPERIMENT: The apple activity test, used in pine vole studies (1,2), was adapted for use on meadow voles (Figure 1, Table 7). An apple with a 3-4 cm slice removed from the apple was placed in a runway and covered with a shingle. After 24 hours the apples were checked for vole tooth marks and recorded as highly or slightly active Percent high activity referred to the percent of apples having a portion larger than a semisphere of 2.5 cm (approx 2.5 g) removed by the voles. Percent activity referred to percent of apples with vole tooth marks. Only % high activity should be presented (Table 7) since it is much better correlated to the vole populations at trap out ($r = 0.87$, $y = 3.35 + 41.36 x$, Figure 1) than % activity ($r = 0.47$, $y = 50 + 30.2 x$, Figure 1). The quadratic regressions were not significant. I believe the reason % activity was not well correlated was because meadow voles are known to range over a large area and will feed to some extent at each monitor site. Therefore, % activity readings for meadow voles may be unusually high even though very low populations actually exist. Since % high activity was dependent on consumption of at least 2.5 g of apple at each site, a better correlation with population was obtained. In addition, I believe weights of apple consumption may give a better correlation with population than this estimate; however, weighing each apple may not be practical when large numbers of plots and sites are to be evaluated. The number of sites per hectare acre may also be important to standardize, since populations of meadow voles may overlap a number of monitor sites. However, this may be difficult because of the great variation in tree numbers per ha, and orchard design from experiment to experiment. In previous pine vole experiments, two sites per tree were established when tree populations were below 70 trees per acre, and one site per tree above about 80 trees per acre (1). This site spacing we believe has allowed population overlap of approx 2 monitor sites in a 24 hour period. Meadow vole overlap may involve many more sites when they are closely spaced; and even a very small population in the vicinity of a monitor site may be detected. In addition, dropped apples in bearing orchard experiments would probably lower visitation and feeding at monitor sites and thus different correlations would be expected compared to a non-bearing orchard situation.

The first 13.4 kg/ha (12 lb/A) broadcast treatment (October) appeared to reduce the % high activity in all of the treated plots, however, a heavy population still appeared to be present as indicated from activity records of November 3 and November 10. For this reason, a second application of baits was applied November 12 at the same rate per acre; untreated plots 13, 14, and 15 were treated November 12 by hand placing baits in runways at the rates indicated (Table 7).

A greater effect from the second application was suspected and may have been the result of a number of low temperature freezes occurring between the first application and the second application and/or the possible accumulation of anticoagulant in the animals. The single hand placed applications of DPN, CPN, and BFC appeared to have given excellent control. However, trail baiting for meadow voles may not be advisable unless sites are covered with some type of site cover to reduce hazard to dogs, cats or other non-target species. This type hazard is much less for pine voles since baits are placed in underground holes and runways and are removed by voles to underground caches.

Table 7. Effect of anticoagulant baits on meadow vole activity and populations.

Treatment	Plot No.		% High activity[zx] Oct 20	Nov 3	Nov 10	Nov 26	Voles/plot[z] (Dec 1-5,1977)	Voles/site[zy] (Dec 1-5,1977)	% Vole control[z]
Control - no treatment	1		83	83	83	71	36	1.50	-
	2		42	42	58	29	20	0.83	-
	3		50	79	71	54	19	0.79	-
		AV	58	68	71	51	25 ± 16	1.04 ± 0.63	0.0
		UL	92	97	90	83			
		LL	21	28	48	19			
Ramik-Brown (DPN)	4		29	29	29	4	6	0.25	77
Broadcast	5		63	33	21	7	9	0.38	65
13.4 kg/ha Oct 22	6		79	21	25	0	9	0.38	65
13.4 kg/ha Nov 12	22		29	33	29	5	4	0.19	82
	23		59	29	53	6	3	0.18	83
		AV	52	29	31	6	6.2 ± 2.6	0.28 ± 0.09	74
		UL	73	34	43	13			83
		LL	30	25	21	1			66
Rozol (CPN)	10		67	42	25	17	2	0.08	93
Broadcast	11		58	63	54	13	2	0.08	93
13.4 kg/ha Oct 22	12		67	42	67	0	3	0.13	88
13.4 kg/ha Nov 12	19		88	29	33	13	1	0.04	96
	20		67	17	42	13	12	0.50	53
	21		46	13	33	13	2	0.08	93
		AV	66	34	42	12	3.7 ± 3.4	0.15 ± 0.14	86
		UL	78	50	55	18			97
		LL	55	18	28	4			76
Talon (BFC)	7		79	29	21	4	0	0.00	100
Broadcast	8		29	25	38	13	1	0.04	96
13.4 kg/ha Oct 22	9		29	29	13	4	1	0.04	96
13.4 kg/ha Nov 12	16		33	8	25	0	0	0.00	100
	17		43	24	57	19	2	0.09	92
	18		83	42	54	21	6	0.25	77
		AV	49	26	35	10	1.7 ± 1.9	0.07 ± 0.08	93
		UL	72	36	48	17			100
		LL	28	15	19	2			88
Hand Placed									
Ramik-Brown (DPN) 11.2 kg/ha Nov 12	13[w]		38	38	21	4	3	0.14	87
Rozol (DPN) 11.2 kg/ha Nov 12	14		38	54	54	13	3	0.14	87
Talon (BFC) 5.4 kg/ha Nov 12	15		33	42	29	0	0	0.00	100

[z] Confidence interval, 90%, determined within columns within treatments. Percent data was transformed to arc sin before upper (UL) and lower (LL) limits were determined.

[y] One site was established per tree by placing an apple in an active runway and covering with a shingle. All plots contained 24 sites except plots 22, 23, and 17 which had 21, 17, and 21 sites, respectively.

[x] Refers to the % of sites having apple consumption greater than a semi-sphere of 2.5 cm.

[w] Plot #13 was dead trapped Oct 21-26 and 37 meadow voles were caught. Invasion from border rows was sufficient by Nov 3 to use as a test plot on Nov 12.

Table 8. Penned pine voles treated with a ground cover spray of Chlorophacinone (CPN) at 0.3 lbs/treated area.

Treatment[x]	Mortality after 14 days
Experiment # 1	
CPN sprayed grass[y] + unsprayed soil	6/8
CPN sprayed soil[z] + unsprayed grass	4/8
Experiment # 2	
CPN sprayed soil[z] + CPN sprayed grass[y]	10/10
No treatment	3/10

[z] Pine voles were allowed to establish runway systems under boards in pens. Boards were removed and trail systems sprayed and boards replaced prior to introduction of animals 1 hour after spraying.

[y] Orchard grass was sprayed in an orchard, allowed to dry, dug, and placed in the feeder box.

[x] Feeders, water bottles, and apples were supplied in addition to grass.

PENNED PINE VOLE EXPERIMENT: Two 3/8 inch hardware cloth wire enclosures were made for testing groundcover spray effects on pine vole populations. Pens were 9 ft X 3.3 ft each and extended 1.5 ft below and 2.5 ft above the soil surface. Animals were allowed 10 days or more to establish tunnels and acclimate to feeding box, water, apples, etc. Voles were live trapped over a 2 day period prior to treatment and returned 1 hour after treatment. During the acclimation period voles did not get along well and some loss was always experienced. The loss of 3 animals in the untreated control over a 14 day period tended to negate these tests (Table 8). However, it did appear in the first experiment that spraying the runways was about as effective as spraying the grass only. In the second experiment all animals were killed when soil and orchard grass were sprayed. I was not happy with the losses of animals in these penned experiments, and some method changes would be necessary to obtain good results. These preliminary results suggest however that contamination of both the runway system and the food supply is important to get the toxicant to the animal as was suggested by Horsfall in 1956 (7).

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