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REVIEW OF CULTURAL AND OTHER CONTROL METHODS FOR REDUCING PINE VOLE POPULATIONS IN APPLE ORCHARDS

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ABSTRACT: The use of cultivation three times a year (May, July, and November) or cultivation plus a residual herbicide twice a year (July and November) greatly aided in the control of pine voles Microtus pinetorum (LeConte) in apple orchards. The use of Chlorophacinone (CPN) or Diphacinone (DPN) baits placed by hand in holes and runs 2-3 weeks after the November cultivation resulted in a very effective control procedure. Without cultivation at least two applications of anticoagulant baits at the rate of 10 lbs/acre each were required to insure adequate control. Due to low apple prices in 1975, large numbers of dropped apples existed under trees when apple and prepared hand baits were applied. We believe dropped apples interfered with control achieved with toxic baits.

INTRODUCTION

Post-harvest application of Endrin to the ground cover has been the major method for the control of pine voles in apple orchards in the Central-Eastern United States for the last 15-20 years (Horsfall 1956a and 1956b). The effectiveness of Endrin in recent years has dwindled due to the development of Endrin-resistant strains of pine voles (Webb and Horsfall, 1967). Many fruit growers now have returned, with poor results, to hand baiting procedures developed in the 1930s. Zinc Phosphide treated oat baits placed in the runs and holes have not resulted in adequate control of the pine vole (Byers, 1975b). Growers, therefore, do not have an effective means of rodent control except in states which have issued state labels for the clearance of chlorophacinone (CPN) and diphacinone (DPN) baits or ground sprays.

Our studies have been designed to find more than one practical solution to the pine vole problem in orchards. For this reason laboratory and field studies not directly related to control were conducted only when basic knowledge was needed.

Habitat

In November 1974 and July 1975 trail systems under at least 20 trees were excavated in orchards with various soil types and tree spacings. We found that pine voles developed a shallow trail system (0-2 inches deep) which we believe functioned mainly as a food gathering area. A typical trail system is located mostly under the canopy of the apple tree with some surface trails leading from tree to tree down the row (Figure 1). The deep tunnel system is usually confined to the tree trunk area (4-5 foot radius); however, if trees are closely spaced, deep tunnels may be found from tree to tree. One or more nests and some underground caches are usually associated with the deep tunnel systems. Nests near the surface may be built during summer and fall periods especially under wood, tar paper, rubber mats, etc. Since large quantities of plant material were not found in the caches in July or November, it appeared to us that the caches were not utilized very well by the animals as food storage areas during environmental stress periods. However, the pine vole has a strong caching instinct and will cache large quantities of plant material or hand baits when these are placed directly in the active trail system. Since the nest(s) and deep tunnel systems are usually located near the tree trunk, we have assumed the tree trunk and large roots provide protection which is not found in more open areas.

Radio transmitters built by R.D. Neely and similar to those previously developed (Neely and Campbell, 1973) were encapsulated in poly tubing and coated with baits of CPN and DPN. The radio transmitters produced bursts of radio frequency energy at 46.78 MHZ with a repetition rate of 500 pulses per second with a maximum range of about 10 m. The transmitters could be easily located at depths greater than 18 inches in the soil. These transmitters were placed in vole runs and holes with CPN and DPN baits and recovered from vole caches after various intervals of time to determine bait condition and location in relation to the nest and tree trunk. Although radio transmitters had a battery life of only 7-10 days, some transmitters were allowed to remain in the soil with the cached bait for longer periods to better observe bait condition. Baits were usually removed from the placement site by the animals in the first 24 hours and were not relocated again by the animals. Also, at no time were baits moved from the original placement site to another tree. The baits were usually cached near the nest sites (never in the nest) in a deep dead

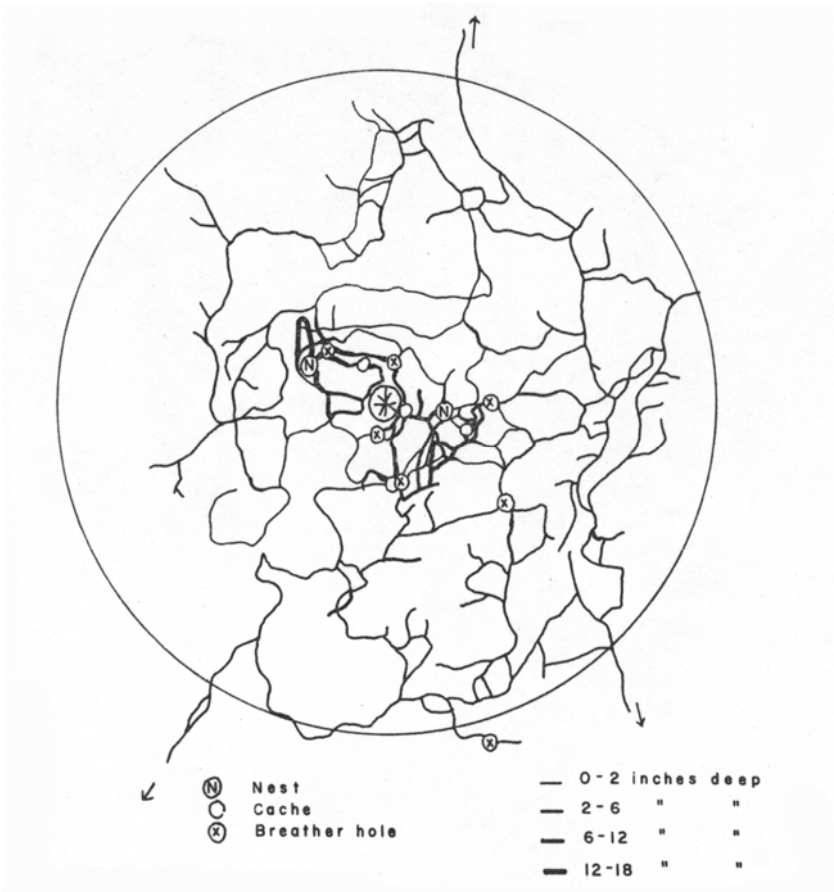

Figure 1. Pine vole shallow and deep tunnel systems.

end tunnel or cache. Baits were found 25.6 ±_7.9 inches from the tree trunk; 25.6 ±_14.9 inches from the nest; 35.8 ± 14.9 inches from the original placement site; and 10.8 ± 1.1 inches deep. Nests were 33.7 ± 11.7 inches from the tree trunk and 8.7 ± 1.2 inches deep. Animals killed by CPN and DPN baits were found in nests and trail systems but never on top of the ground in these studies. Caching instinct can be utilized to relocate baits or encapsulated fumigants to a more central location within the population.

Pine vole populations in an apple orchard may be 10 times that found in any other natural habitat because the cultural management of most orchards happens to coincide with the voles' basic requirements for survival. Conditions which provide an abundance of litter, a diversity of vegetation, and proper soil moisture and soil temperature for burrowing make for an ideal habitat. Constant mowing and fertilization encourage maximum root and shoot growth of grasses and broad leafed plants near the soil surface. These plants provide ample feed in most seasons of the year. Tree leaves provide shade which reduces soil temperature fluctuations in summer, but more importantly the dropped leaves add to the natural mulch and cover in the winter. The tree leaf and ground cover mulch reduces fluctuations in soil temperature and maintains a uniform soil moisture level for burrowing throughout most of the year.

Population Distribution

Pine vole populations exist in colonies with a very limited home range which may encompass a 1-4 tree area somewhat dependent on tree spacing. Population variations are not easily predicted from the extent of burrowing or other signs, and vary greatly from tree to tree. For example, we have trapped as many as 22 voles under one tree while simultaneously trapping adjacent trees in a block with 54 trees per acre. This tree therefore had a population equivalent to 1,188 voles per acre. If we assume the roadway space (approximately 1/3 of the orchard floor) is not infested (no trail system can be found), the effective

population per acre for this tree would be 1,782 voles/acre. In the same block we also found trees with no voles. Therefore, we believe population estimations over large acreages do not reflect the potential for damage at certain trees dispersed throughout a planting and we believe damage will start where populations are largest. In orchards where a serious pine vole problem exists, it is not uncommon to find as many as 1/10 of the trees with 8 or more animals/tree. Since examination of the trail and tunnel system usually does not give a very good indication of the number of voles residing in the trail system, rates per acre of hand placed baits should not be reduced or regulated according to what the grower may "think" the population to be. However, if no trail system exists, there is high probability that no pine voles exist at that tree.

We believe pine vole populations seek an equilibrium with the habitat. The more ideal the habitat the greater the rate of population increase and ultimate population level. Seasonal environmental changes cause dramatic changes in habitat which in the summer and fall period result in high population development. In the winter, not only is the food supply limited by soil and ground cover freezing, but I believe the range and movement of animals in the trail system is limited to areas closer to the next sites further reducing the available food supply. These environmental changes create less desirable conditions for vole survival and may lead to tree damage, since the deep tunnel system is located in the vicinity of the tree trunk and large roots.

Basic Control Assumptions

We have assumed that high populations of voles per unit area are more hazardous than low populations simply because large numbers of voles can do more damage than can small numbers. A habitat which is ideal for high vole populations can be more protective of trees (Horsfall et al., 1974) if and only if the populations are kept low through a highly effective control method. Since Endrin was originally cleared at a dosage level higher than actually required, it had considerable margin for error in application technique, dosage, and ground cover, and was therefore a highly effective damage control agent under most orchard conditions. In orchards where Endrin has been used annually for 7-10 years, resistant strains (Webb and Horsfall, 1967) probably have developed and alternative control methods must be now used. Since most of the alternatives to Endrin do not have the margin of error or the control capability Endrin ground sprays enjoyed when first used, I think it wise to develop a habitat not conducive to high pine vole populations. In addition, rapid development of resistance is more likely when high populations are involved.

MATERIALS AND METHODS

Assessment of Orchard Situation

The potential for vole damage must be assumed if voles are present in the tunnel system since factors (environmental stress periods, pine vole population levels, reproduction rates and other factors) affecting damage cannot be easily predicted in time to control the population. This assumption has led to the assessment of treatment effects based on the vole activity in the tunnel system as measured by a reduction in active sites (vole tooth marks on a cut apple placed at stations 2-6 inches below the soil surface). A treatment which reduces the feeding at these stations from 90-100% to 5-10% is considered as eliminating the voles in 90-95% of the tunnel system. The activity method has been discussed at length in previous papers (Byers and Young, 1976; Byers 1975a; Horsfall, 1956b) and will not be discussed here. All plots are replicated three times if not otherwise indicated.

Growers have used these methods for assessing their own orchard treatments. Prior to orchard treatment growers place an apple 2-6 inches below the soil surface in a pine vole tunnel at each of 40-50 trees perpendicularly or diagonally across rows. Twenty-four hours after placement growers check the placed apples for tooth marks, make a record, and calculate the percent of apples with vole tooth marks. After the orchard is treated with a ground spray or bait, growers make 24-hour checks for activity and calculate percent activity at regular monthly intervals. This figure gives the grower an idea of the percent of trees which have a potential for damage. Chlorophacinone and Endrin ground sprays should show their full effects in about 30 days and hand baits 14-30 days depending on the type of bait. To mark the original location of the apple placement site, flags may be tied to stakes or trees, or each site may be covered with sections of straw, plastic trash can lids, rubber mats, wood slabs, tar paper, shingles or many other suitable materials. Site covering materials should be chosen which will not blow in the wind, weigh at least 2-3 lb., and will last for many years.

RESULTS AND DISCUSSION

Control Methods

1. Hand baits--Zinc Phosphide grain baits applied by hand (8 lbs./acre) in the runway system or placed in bait tubes on top of the ground have not given adequate control of pine voles (Table 1). Zinc Phosphide coated apple slices are more effective than grain baits but still do not provide adequate control (Byers, 1975b).

Table 1. Effect of various Zinc Phosphide treatments applied at 8 lbs/acre on pine vole activity at Berryville, Virginia, treated January 4, 1973.

Treatment[z]	No. sites per plot	% Activity[y]				
		Jan 1	Jan 17	Jan 25	Mar 7	Mar 14
1. Control	24	79	87.5	83	91	96
2. Peanut butter (in bait tubes) 5% Zn_3P_2	24	83	79	79	87.5	96
3. Oat seeds (in bait tubes) 2% Zn_3P_2	24	87	91	87.5	96	87.5
4. Peanut butter encapsulated 5% Zn_3P_2 (in trail system)	22	91	91	82	77	95
5. Oat seeds (in trail system) 2% Zn_3P_2	24	96	83	75	83	87.5
6. Peanut butter (not encapsulated) 5% Zn_3P_2 (in trail system)	28	90	90	77	94	96

[y]Apples placed in 2 holes or runs located 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.

[z]Treatments were not replicated.

Hand placement of Chlorophacinone (Rozol) and Diphacinone (Ramik/Brown) anticoagulant baits can be very effective if two applications are made at 30-60 day intervals at the rate of 10 lb./A each (Figure 2, Table 2, Table 3). These materials have label clearance in a number of states but do not have a national EPA label. We believe that better control can be achieved when the baits are applied in mid-winter at the time when normal food supplies have diminished. Since damage can start as early as mid-November, the first hand bait application should be made before the first of December. The second application should be made in late December or January to prevent late winter (February & March) damage. Bait tubes filled at regular intervals with OPN baits have achieved excellent control in some plots but not in others (Table 2), Since this animal does not spend large amounts of time on the surface, animals are not as likely to find the bait stations as easily as would meadow voles, Microtus pennsylvanicus (Ord.). Further studies are underway.

2. Ground sprays--Endrin is cleared by the EPA for use in the dormant season for the control of pine voles in apple orchards and may be very effective in orchards with proper ground cover. Where Endrin has been used for over 10 years (Webb and Horsfall, 1967) resistant strains probably have developed and control may be inadequate. In one experiment Endrin was compared to Chlorophacinone (CPN) ground spray in a 7 acre orchard block which had been treated annually with Endrin for over 10 years (Figure 3). Endrin had no effect on the population whereas CPN gave marginal control. The plots were treated with DPN and CPN baits in late February with good results. Note also how rapidly the population returned in the five months from May through October 1975. Data was collected at 40 sites in each of the two 3-5 acre sections using one site per tree.

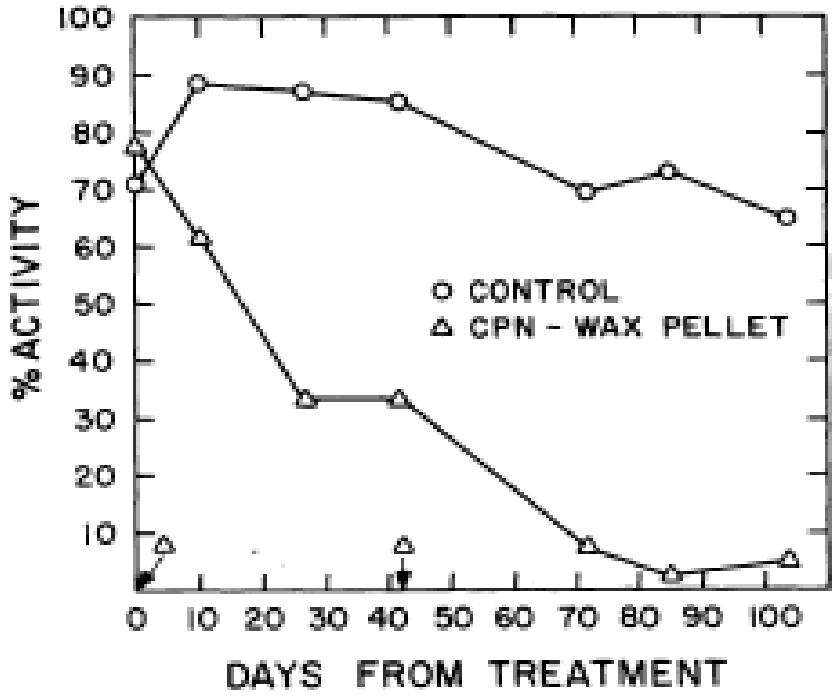

Figure 2. Chlorophacinone hand placed baits gave excellent control of voles in two applications of 10 lbs/A each 42 days apart.

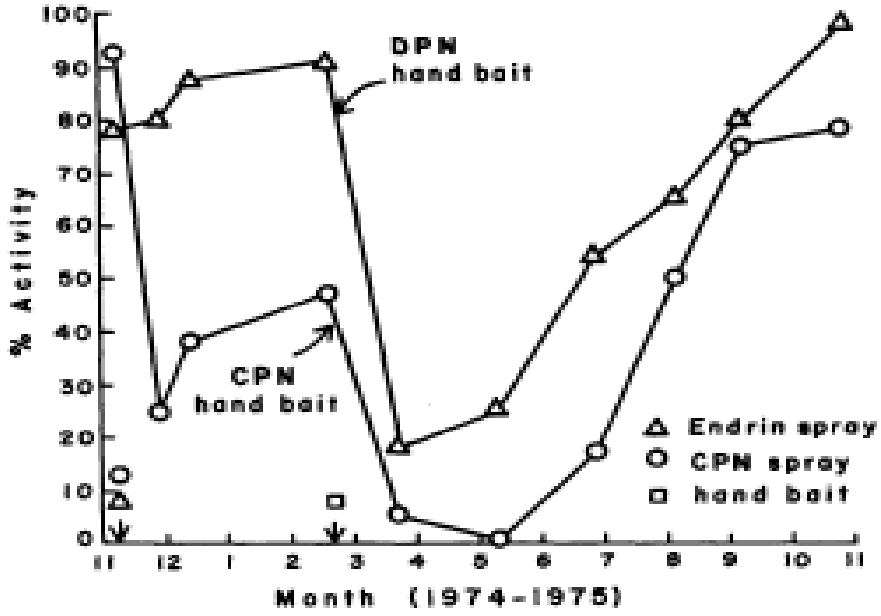

Figure 3. Endrin applied at 2.4 lbs/A did not control pine voles (probably because of Endrin resistance). Chlorophacinone ground spray applied at 0.2 lbs/A gave some control. Both CPN and DPN hand baits were effective when applied in February.

Table 2. Effect of hand placed Chlorophacinone and Diphacinone prepared baits on pine vole populations in apple orchards (1975).

Treatment	No. of plots	Rate lbs/A	Date treated (1975)	% Activity[yz] Oct 14	Oct 24	Nov 4	Nov 12	Dec 5	Voles/site Dec 8-12
1. Control	3			78 ab	63 a	54 a	65 a	47 a	.40 a
2. Ramik-Brown DPN .005%	3	10	Oct 14	85 ab	43 ab	44 a	43 ab	38 ab	.25 ab
3. Ramik-Brown DPN .005%	3	20	Oct 14	83 a	57 a	49 a	50 ab	33 ab	.08 b
4. Ramik-Brown DPN .005%	3	10 + 10	Oct 14 Nov 14	83 ab	48 ab	49 a	44 ab	1 c	.03 b
5. Ramik-Brown DPN .005%	3	bait tubes	Oct 14 Oct 31	75 ab	46 ab	30 a	28 b	16 bc	.21 ab
6. Rozol CPN .005% (3/16 inch wax-grain pellets)	3	10 + 10	Oct 14 Nov 14	72 ab	18 b	17 a	26 b	13 bc	.04 b
7. Rozol CPN .01% (3/16 inch wax-grain pellets)	3	10 + 10	Nov 14 Oct 14	67 b	12 b	17 a	16 b	1 c	.01 b

[y]Apples placed in 2 holes or runs located 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.

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

Table 3. Effect of Chlorophacinone on pine and meadow vole control in the Hudson Valley, New York.

Treatment	No. of plots	Rate lb/A	Date treated (1975)	% Activity[xy] Nov 12	Nov 24	Dec 2	Dec 9	Voles/site Dec 9-11
1. Control	3			78 a	85 a	84 a	75 a	.99 a
2. Hand bait CPN 0.005% (3/16 inch wax-grain pellets)	4	10 + 10	Nov 13 Dec 2	74 a	26 c	21 b	6 b	.01 b
3. Ground spray CPN	3	0.2	Nov 13	72 a	62 b	63 a	44 a	.55 a
4. Ground spray[z]	1	0.4	Nov 13	71	38	46	21	.21

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

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

[z]Only one replicate.

Chlorophacinone ground cover sprays have label clearances in a number of states but do not presently have an EPA label. The label states that the rate per acre should be 0.2 lb./A. However, this is the rate per geographic area of orchard (which includes unsprayed roadways) and not sprayed acres. Since approximately 2/3 of the orchard floor is sprayed in most mature orchards, the actual ingredient per sprayed acre should be 0.3 lbs./A sprayed. We recommend 400 gallons of water per geographic acre (or approximately 600 gallons/sprayed acre) and 500-600 psi pressure to insure adequate penetration of the leaf and grass mulch. This is necessary to coat the crowns and petioles of plants growing adjacent to or into the tunnel system. Cultural systems which destroy the surface tunnel system prior to ground sprayed toxicants may reduce the effectiveness of the technique because the toxicant must be ingested by the vole via plant material. Ground sprayed toxicants also have their greatest effect just after harvest prior to the onset of ground cover dormancy. The application of CPN by growers in 1973 and 1974 using hand gun, boom, and an adapted airblast sprayer gave good control (Byers, 1975a and Byers, 1975b). Ground sprayed CPN was not effective (Table 3) in an experiment conducted in the Hudson Valley, New York. We believe the toxicant was washed from the plant material by rain. Two applications of the CPN hand bait were extremely effective. The population consisted of 60% meadow voles and 60% pine voles. Activity was monitored at 24-28 sites (2 sites/tree) in each plot and plots were replicated 3 times.

3. Cultural Management -- Cultural management of orchards directed toward an alteration of pine vole habitat has been practiced by some growers for many years. Data to support such an approach to control are almost non-existent. For this reason we initiated a study with Henry Chiles at Batesville, Virginia, who cooperated very well with us on a cultivation experiment using a new orchard cultivator called a Smitty Tree Hoe (Byers and Young, 1974). Three plots of Tree Hoe cultivation were compared to three uncultivated plots (Figure 4). Cultivations were performed on May 8, July 2 and November 21 1973. These three cultivations decreased the active sites to about 8% compared to the uncultivated check of 88% as of January 4, 1974, and remained at that level or below until March. The orchard was abandoned in 1974 and no cultivations were performed until November 1974. An adjoining peach orchard was cultivated (November 1974) driving voles into the plot area. Subsequent cultivation of plots resulted in some control of voles. Both cultivated and uncultivated plots were treated twice with CPN at 10 lb/A at about a 20 day interval in December 1974. The populations in both plots were destroyed and the plot area was abandoned in September 1975.

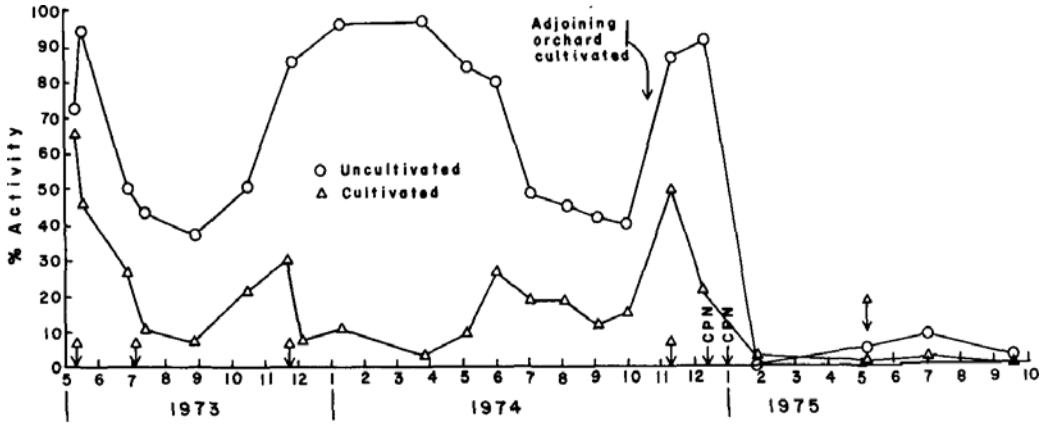

Figure 4. Effect of Smitty Tree Hoe and CPN hand baits on pine vole activity.

In cooperation with Dr. Roger Young and the West Virginia University Experiment Farm, Kearneysville, West Virginia, we examined Dr. Young's Simazine herbicide plots for pine vole activity (Byers and Young, 1974). Simazine was applied annually for 10 years to 4 replicates of 4 trees each in a single tree row width band presently 12 feet wide. All vole activity and vole catches in the Simazine plots were made at tree numbers 1 and 4 which were directly adjacent to the untreated control areas in the same row. Trees in

position No. 1 and 4 acted as buffers for trees 2 and 3 in the Simazine plots. No vole activity was found at trees 2 and 3. Considerable root sucker growth was apparent around most trees with some leaf and other litter existing near the tree trunk even in the Simazine plots. No holes or activity were found in these root sucker areas near the trunks in the Simazine treated plots. We therefore feel that the lack of tunnels surfacing near the tree trunk indicated that the voles were not tunnelling under the herbicide strip to get to the trees. Other herbicide plots appeared to be infested with pine voles to varying degrees depending on the degree of weeds and litter existing under the trees. Herbicides applied to an existing pine vole population did not provide control and trees were damaged in 1974. Herbicides can only aid in preventing pine vole infestations when started in the early life of an orchard before a deep tunnel system has been established.

Another cultural experiment (Figure 5) was initiated at the West Virginia University Experiment Farm with Dr. Young in July 1974. Historically this orchard has had an extremely heavy pine vole population with severe damage where no control was used. Three replicates of approximately 40 trees each were selected for the following treatments: 1) control, 2) cultivation+herbicide (July + November), 3) cultivation (November), 4) cultivation (May, July + November), 5) herbicide only (July). The objective of the residual herbicide treatments was to maintain bare ground culture whether or not in combination with cultivation. The herbicide applications were the same width as the cultivated band (10 ft. wide). This experiment is to be continued for a number of years to determine if voles can be controlled with a change in orchard culture. The effect of cultivation was greatly enhanced by the use of a residual herbicide applied immediately after cultivation. However, in my opinion, none of the treatments were sufficiently effective after the first 5 months to be considered an adequate control procedure. Cultural control of an existing population has not been totally successful in the short term and there continues to be the need for additional toxicant control in most orchard situations. One application of OPN hand bait in early December 1974 to all plots gave adequate control, but a second application in January should have been applied if this were a commercial orchard situation.

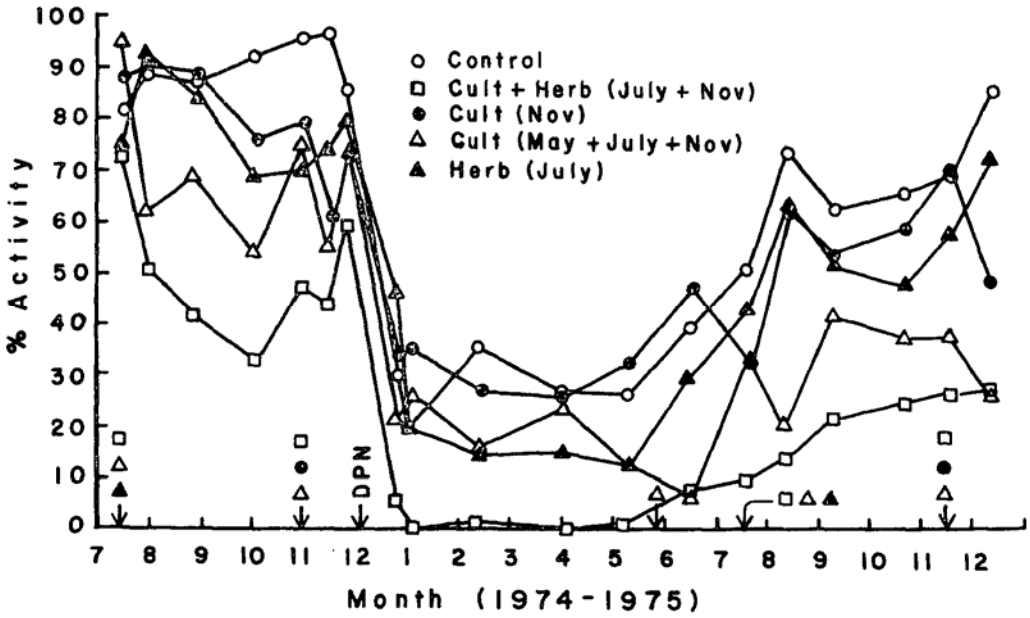

Figure 5. Effect of Smitty Tree Hoe and DPN hand baits on pine vole activity.

Examination of the pine vole tunnel system in treatments 2, 4 and 5 (October 1974) showed that pine voles appeared to be feeding in the ground cover adjacent to the cultivated and/or herbicide treated strip. In the cultivated treatments (2 and 4), the pine voles tunnelled in the loose soil created by the Smitty Tree Hoe (no evidence of deeper tunnelling due to cultivation was found). Cultivation in November disrupted the tunnel system again and temporarily cut off the pine vole from its food supply. We believe that this disruption

of the tunnel system may cause many voles to either move from the area or starve before a new tunnel system can be built to the adjacent food supply. Continued use of the tree hoe and herbicides for over a year may reduce the vole problem considerably in some orchard situations (Figure 5).

Cultivation can destroy the surface tunnel system where 70-80% of the tunnels exist; it can destroy some nests, voles, food supplies and cover. After harvest, cultivation can incorporate fallen tree leaves which would normally create a winter mulch and cut up the dropped apple supply which would otherwise give the voles an added food supply for a number of months. Herbicides can be used to complement the cultivation method but cannot replace it.

The objective of the cultural management technique is to alter the vole's habitat sufficiently so that the animal cannot exist in the environment immediately adjacent to the tree and to disperse heavy populated areas. At the present time we feel that cultural management procedures should be started during the months of May through July to discourage the vole population from building to a high level. Another cultivation after harvest to destroy the dropped apples, fallen tree leaves, and ground cover is extremely important. Cultural management may be dangerous when only a partial job is done or when cultural management has been used one year and no control used the following year. Certain orchard terrain and extremely rocky soil cannot be cultivated; and thus, the need for chemical control methods will still exist for many years to come.

4. Combination of Control Methods -- The most effective method for vole control has been the combination of cultural change and anticoagulant baits to keep populations at a low level throughout the year (Figure 5). The cultivation-herbicide band treatment (at least 10 ft. wide down the tree row in July and November) plus one hand bait application (10 Ib/A) in December has resulted in effective control.

The philosophies of the cultural management approach and the toxicant ground spray approach appear to be diametrically opposite. The creation of an above ground habitat through the proper seeding of plots to encourage above ground activity depends on the availability of an effective ground spray toxicant (Horsfall et al., 1974). Since many orchards have Endrin resistant strains, we are suggesting that cultural changes plus hand baits may be the only alternative in some orchards until new ground spray materials are available (CPN ground sprays are now available in some states). Cultural management of vole populations and ground sprayed toxicants can be effective in an orchard if each is used properly in relation to the other. For example, if a 10-15 foot wide bare ground strip is maintained under the tree line down the tree row, the ground sprayed toxicant must be applied to the ground cover between the tractor wheel and the bare ground strip at the full rate per geographic acre. The application of the toxicant to the bare ground will not result in control since the toxicant must be ingested via the plant material. If a dropped apple supply under the trees is being utilized by the animals, control may be hampered.

New Toxicants

A niacin antimetabolite RH 787, made by the Rohm and Haas Co., was very effective in reducing pine vole populations in experimental plots (1974 when applied to apple slices at 1% on a weight/weight basis and dispensed in holes and runs at the rate of 10 lbs. of apple per acre (Byers, 1976). In 1975 we did not get the same level of control we experienced in 1974 (Tables 4 and 5). We believe the large numbers of apples on the ground and/or actively growing ground cover at the time of hand baiting greatly reduced feeding on the toxic baits. Destruction of the dropped apple supply may be a necessary when using apple baits.

The RH 787 meal pellets were not removed well from the placement sites and were not sufficiently effective in two applications at 10 lb/A each nor was one application of RH 787 (Tracking powder at 4%) on apple slices (Table 4). Further development of a prepared bait will be required. This bait does not have a state or federal label at the present time.

Another anticoagulant made by 101, Difenacoum (DFC), may be very useful in control of pine voles. The preparation (2% at mix) used to coat apple baits at 1% inhibited soil fungi attack and baits were available to the population over a long period. We believe this apple bait preparation to be more effective when dropped apple supplies are minimal since it was as effective as RH 787 (1%) which was extremely effective in 1974 (Tables 4 and 5). This bait does not have a state or federal label at this time.

Table 4. Effect of various apple baits for pine vole control.

Treatment	No. of plots	Rate lbs/A	Date treated	% Activity[yz] Oct 14	Oct 29	Nov 7	Nov 14	Voles/site Nov 17-21
1. Control	3	--		80 a	66 a	61 a	72 a	1.17 a
2. Apple DFC 0.02%	3	10	Oct 16	82 a	28 bc	11 c	40 ab	.28 b
3. Apple CPN 0.02%	3	10	Oct 16	79 a	11 c	25 bc	43 ab	.40 b
4. Apple RH 787 1%	3	10	Oct 16	86 a	26 bc	24 bc	36 ab	.39 b
5. Apple RH 787 (0.4%, TP)	3	10	Oct 16	82 a	32 b	53 a	40 ab	.71 b
6. Grain pellet RH 787 1%	3	10 + 10	Oct 16 Nov 7	80 a	37 b	44 ab	27 b	.54 b

[y]Apples placed in 2 holes or runs located 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.

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

Table 5. Effect of various apple baits on pine vole control.

Treatment	No. of plots	Rate lbs/A	Date treated (1975)	% Activity[yz] Dec 2	Dec 18	Jan 2
1. Control	3	--		60 a	68 a	66 a
2. Apple DFC 0.02%	3	10	Dec 3	59 a	19 b	27 cd
3. Apple CPN 0.02%	3	10	Dec 3	58 a	29 b	33 c
4. Apple RH 787 1.0%	3	10	Dec 3	58 a	21 b	18 d
5. Apple Furadan 0.75%	3	10	Dec 3	60 a	56 a	51 b
6. Apple Temik 0.45%	3	10	Dec 3	58 a	32 b	37 c

[y]Apples placed in 2 holes or runs located 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.

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

The CPN apple bait preparation (Tables 4 and 5) was prepared from a 2% dry concentrate put on cut apples at 1% by weight. When dropped apple supplies are minimal we believe this to be a good preparation since it was as effective as RH 787 (1%). The use of the CPN-mineral oil concentrate on cut apples in previous tests did not result in an effective bait preparation in field trials (Byers, 1975b). The 3/16 inch diameter CPN pellets performed very well in all 1975 tests (Table 2 and 3) when compared to the 1974 results (Byers and Young, 1976).

CONCLUSION

Historically, we have seen almost total dependence on one compound and one method--ground cover sprays of Endrin. In many orchards where Endrin had been used for many years resistant strains have developed (Webb and Horsfall, 1967) and are leaving many growers with no alternative method.

For this reason, we currently have an emergency situation. Federal clearance for two or three highly effective alternative toxicants will be very important to the survival of a major portion of the Eastern U.S. apple industry. In addition, research programs which can find a solution to the problem which does not require federal clearances for implementation will be of major importance.

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