March 1977

PINE VOLE CONTROL RESEARCH IN VIRGINIA

Ross E. Byers
Virginia Polytechnic Institute and State University

PINE VOLE CONTROL RESEARCH IN VIRGINIA

Ross E. Byers
Associate Professor of Horticulture
Winchester Fruit Research Laboratory
Virginia Polytechnic Institute and State University
Winchester, Virginia 22601

ABSTRACT: A number of anticoagulant baits were found to be effective for the control of pine voles in apple orchards. The more toxic and acute the anticoagulant bait, the more effective the compounds appeared to be in field trials. A single 10 lb/A application of ICI 581, LM 637, and CPN gave excellent control in 1976 trials. Apple baits of ICI 581 and RH 787 also performed very well as a single 10 lb or 5 lb application per acre, respectively. Endrin applied to an orchard with a history of 10 years or more of annual applications did not control the voles. An application of Endrin in 1976 to an orchard not treated with Endrin since 1973 gave some control of voles, but it was considered inadequate.

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.

Since fruit growers in most eastern states have been dissatisified with pine vole control methods, the Department of Horticulture at VPI & SU has placed high emphasis on this research project since its solution is vital to the survival of the apple industry. Our vole control program has been designed to research any method for reducing or eliminating economic damage to fruit trees. The two main approaches have been the use of 1) toxicants and 2) culture to reduce population levels and thus reduce damage. We are also studying the nature of apple rootstock susceptibility and resistance and have surveyed over 100 apple clones for their potential resistance.

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 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. This data was based on 22 trees. 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.

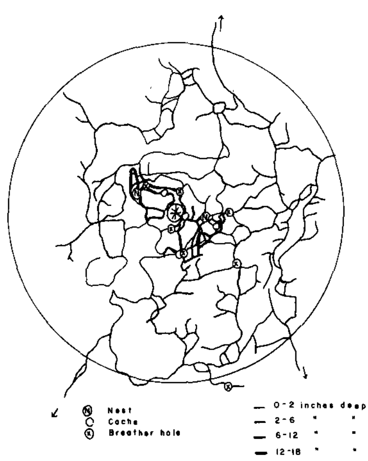

Figure 1. Pine vole shallow and deep tunnel systems.

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 broadleafed 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 nest 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.

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. The quadratic regression equation of percent activity on voles trapped per site in 87 plots conducted in 1975 and 1976 was $\underline{y = 7.54 + 78.02 - 17.74}$ and had a coefficient of determination of (R^2) of .77 (Figure 2). Growers have also used the activity method for assessing the potential hazard. We suggest that whenever the activity rises to over 20% in the fall and winter period some type of treatment should be made.

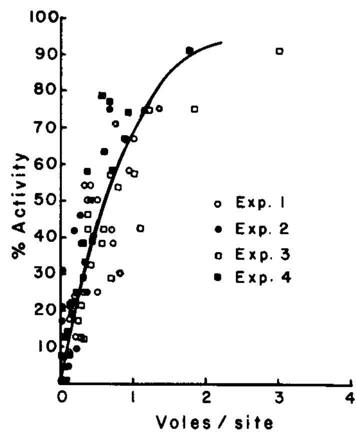

Figure 2. Regression of percent active sites on voles/site.

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.

CONTROL METHODS:

1. Hand baits--Zinc Phosphide grain baits applied by hand (8 lb/A) in the runway system or placed in bait tubes on top of the ground have not given adequate control of pine voles (Byers, 1976). Zinc Phosphide coated apple slices are more effective than grain baits but still do not provide adequate control (Byers, 1975b).

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 (Byers, 1976). 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 to prevent late winter (February & March) damage. Bait tubes filled at regular intervals with DPN baits have achieved excellent control in some plots but not in others. 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 1975 with good results. Note also how rapidly the population returned in the five months from May through October 1975. The DPN treatments in January 1976 and December 1976 appear to be successively less effective than the February 1975 treatment. This could be due to resistance or changes in formulations. The Endrin application in November 1976 did not give adequate control of voles when applied to the area of the orchard not treated with Endrin since the fall of 1973. Data was collected at 40 sites in each of the two 3.5 acre sections using one site per tree.

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 lb/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

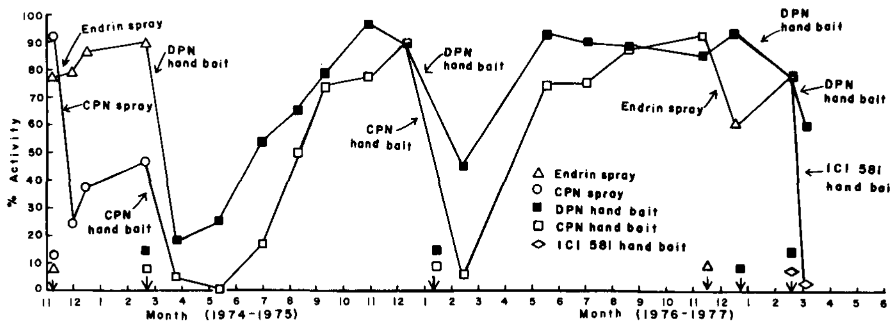

Figure 3. Endrin applied at 2.4 lb/A did not control pine voles (probably because of Endrin resistance). Chlorophacinone ground spray applied at 0.2 lb/A gave some control. Both CPN and DPN hand baits were effective when applied in February 1975. Endrin applied in November 1976 did not give adequate control. Two applications of DPN did not give adequate control in 1977 but ICI 581 gave excellent control.

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 (Byers, 1976) in an experiment conducted in the Hudson Valley, New York. We believe the toxicant was washed from the plant material by rain.

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.

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

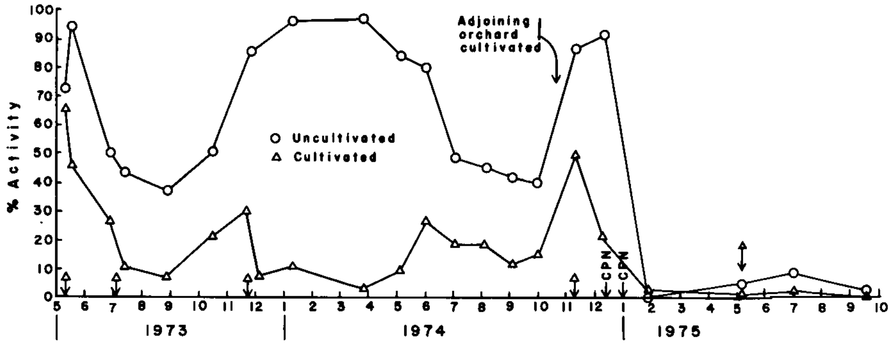

Figure 4. Effect of Smitty Tree Hoe and CPN hand baits on pine vole activity.

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 DPN 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.

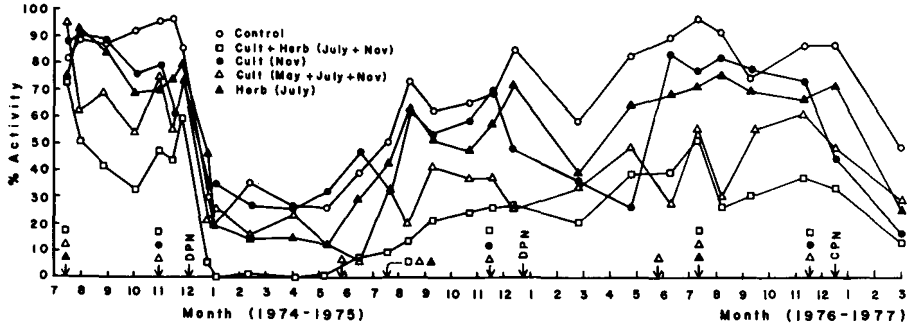

Figure 5. Effect of Smitty Tree Hoe, DPN, and CPN hand baits on pine vole activity.

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.

NEW TOXICANTS: A new anticoagulant, ICI 581, made by Imperial Chemical Industries, has performed very well in field (Table 1) and laboratory trials. An apple bait formulation (0.005%) and a prepared pelletted formulation (0.005%) dispensed in a single application by hand at 10 lb/A in runs and holes gave excellent control in the 1976 trials (Table 1).

Another new anticoagulant, LM 637, supplied by Chempar Chemical Company, in a pelletted bait formulation (0.005%) gave excellent control dispensed in one application at 10 lb/A (Table 1).

The Chlorophacinone (Rozol) bait now supplied as a 3/16 inch pellet has been superior to the 3/8 inch pellet and in 1976 gave excellent control in one application at 10 lb/A (Table 1). However, in the past we have suggested a second application at a 20-40 day interval.

The Diphacinone bait (Ramik-Brown) has given rather poor control when only one application has been used (Table 1); however, the second application at a 20-40 day interval at 10 lb/A each has given excellent control in previous experiments (Byers, 1976). This material will not melt in bait tubes under heat conditions as will the baits prepared with wax ingredients such as Rozol.

A niacin antimetabolite RH 787 was very effective in reducing pine vole populations in 1974 and 1976 experimental plots when technical RH 787 was applied to apple slices at 1% on a weight/weight basis and dispensed in holes and runs at the rate of 10 lb of apple per acre (Table 1). In 1975 we did not get the same level of control we experienced in 1974 and 1976, and we believe that large numbers of apples on the ground at the time of hand baiting greatly reduced feeding on the toxic baits in 1975. Destruction or removal of the dropped apple supply may be necessary when using this material on apples. This material should also kill anticoagulant resistant animals.

In 1976, a RH 787 meal pelletted bait was removed very well from the placement sites, but was relatively ineffective in a single application at 5 lb/A (Table 1). Further development of a prepared bait will be required. This compound does not have a state or federal label at the present time.

LABORATORY STUDIES: Since most prepared baits spoil at various rates in the field depending on soil temperature and moisture conditions, the length of time required for a vole to receive a lethal dose may be very important to the degree of control achieved. Presenting bait to caged animals in a small aluminum cup over various periods of time (Table 2) has shown that some anticoagulants must be available to the animals over a period of as much as 5 days before 90% or more of the animals are killed. The most acute anticoagulant bait preparation is ICI 581 followed by LM 637, CPN, and DPN respectively. The degree of control achieved (Table 1) appears to be directly related to the acute nature of the anticoagulant bait preparation. Studies with RH 787 have shown that laboratory and field studies can be entirely different, and therefore I believe that laboratory data has great limitations and cannot be relied upon to predict field control potential. This material is very effective in the laboratory as an apple (Byers, 1976) or 4% meal bait. However, the apple bait performed very well in the field (Table 1), but the 4% grain pelletted bait did not (Treatment 4).

Table 1. Effect of various baits on pine vole control treated November 3-5, 1976.

Treatment	No. of plots	Rate lb/A	% Activity[y] Oct 29	Nov 2	Nov 17	Nov 24	Voles/site (November 29-December 6)
1. Control	3	-	81 a[z]	79 a	79 a	76 a	0.99 a
2. Apple RH 787 (1%)	3	5	52 b	78 a	8 cd	7 c	0.06 c
3. Apple ICI 581 (0.005%)	3	10	72 ab	82 a	6 cd	11 c	0.06 c
4. Pellet RH 787 (4%)	3	5	80 a	79 a	81 a	73 a	0.84 ab
5. Pellet ICI 581 (0.005%)	3	10	77 ab	83 a	0 d	4 c	0.06 c
6. Pellet LM 637 (0.005%)	3	10	70 ab	81 a	15 c	11 c	0.12 c
7. Pellet Rozol-CPN	3	10	88 a	83 a	13 c	5 c	0.04 c
8. Pellet Ramik-Brown DPN (0.005%)	3	10	67 ab	80 a	49 c	32 b	0.31 c
9. Bait tubes-pellet RH 787 (4%)	3	5	77 ab	82 a	60 b	57 a	0.47 bc

[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 2. Summary of free choice pine vole feeding trials on prepared pelletted baits.

Treatment[x]	Exposure (days)	Bait consumed (grams)	Bait cached (grams)	Mortality	Days to death
Control	-	--	--	0/10	--
CPN	1	4.5 ± 1.7	12.8 ± 2.4	4/10	5.3 ± 2.0
CPN	2	8.0 ± 2.2	13.2 ± 5.6	6/10	4.8 ± 1.2
CPN	3	11.3 ± 4.4	24.4 ± 11.6	10/10	5.3 ± 0.8
Control	-	--	--	0/10	--
DPN	1	4.3 ± 0.7	2.4 ± 2.3	0/10	--
DPN	2	7.8 ± 2.1	7.3 ± 4.3	0/10	--
DPN	3	10.6 ± 2.0	7.6 ± 5.4	4/10	5.0 ± 1.3
DPN	4	10.9 ± 3.3	9.6 ± 11.7	7/10	5.3 ± 1.2
DPN	5	10.9 ± 3.3	13.8 ± 6.4	9/10	5.6 ± 1.0
Control	-	--	--	0/10	--
LM 637	1	3.5 ± 1.1	9.4 ± 4.3	7/10	7.0 ± 1.9
LM 637	2	9.6 ± 2.7	17.0 ± 5.3	9/10	5.2 ± 1.6
Control	-	--	--	0/10	--
ICI 581	1	1.8 ± 0.6	5.7 ± 4.1	9/10	6.1 ± 1.2
ICI 581	2	3.7 ± 1.3	17.9 ± 8.3	10/10	6.4 ± 1.8
Control	-	--	--	0/10	--
RH 787	1	0.3 ± 0.2	8.2 ± 4.2	10/10	1

[x] Footnote continued on next page.

Table 2, continued

[x] Single caged pine voles given adequate water and feed (Lab-Blox, Allied Mills, Inc.) were given 20 grams of bait each exposure day. Each day amounts cached and consumed were determined. Mortality was observed for a 21-day period following the initiation of the test. All anticoagulants, CPN, DPN, LM 637, and ICI 581 baits were formulated at 0.005% concentration. The RH 787 was a 4% meal pelletted bait.

ECONOMICS OF CONTROL METHODS: The use of certain control procedures has limitations imposed by factors other than the total cost per acre of the application. Skilled reliable labor required for hand baiting, capital investment for tree hoe and tractor, or availability of proper spray equipment all influence the grower's selection of a control method. However, through observation of grower vole control methods and our own plot work we have made some estimates of the costs (Table 3).

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.

LITERATURE CITED

Byers, R. E., R. S. Young, and R. D. Neely. 1976. Review of cultural and other control methods for reducing pine vole populations in apple orchards. Proc. 7th Vert. Pest Control Conf., Monterey, Calif. p. 242-253.

__________. 1976. New compound (RH 787) for use in control of orchard voles. J. Wildl. Mgmt. (in press).

__________, and R. S. Young. 1975. Pine vole control with anticoagulant baits. J. Amer. Soc. Hort. Sci. 100(6):691-694.

__________. 1975a. A rapid method for assessing pine vole control in orchards. Hort. Sci. 10(4):391-392.

__________. 1975b. Effect of hand baits and ground sprays on pine vole activity. Hort. Sci. 10(2):122.

__________, and R. S. Young. 1974. Cultural management of pine voles in apple orchards. Hort. Sci. 9:445-446.

Hayne, D.W. 1951. Zinc Phosphide: Its toxicity to pheasants and effect of weathering upon its toxicity. Michigan Agr. Exp. Sta. Quart. Bul. 33(4):412-425.

Horsfall, Frank, Jr. 1956a. Rodenticidal effect on pine mice of Endrin used as a ground spray. Science 123:61.

________________. 1956b. Pine mouse control with ground-sprayed Endrin. P. Amer. Soc. Hort. Sci. 67:68-74.

________________, R. E. Webb and R. E. Byers. 1974. Dual role of forbes and rodenticides in the ground spray control of pine mice. Proc. 6th Vert. Pest Control Conf., Anaheim, Calif. p. 112-126.

Neely, R. D. and R. W. Campbell. 1973. A system for gathering small mammal mortality data. USDA Forest Serv. Res. Pap. NE 280. 6 p.

Webb, R. E. and Frank Horsfall, Jr. 1967. Endrin resistance in the pine mouse. Science 156:1762.

Table 3. Economics of pine vole control methods in apple orchards (November 1974).

Control method	Man hours per A	Labor/A @ $3.00/hr	Equipment & maintenance cost/A	Pesticide cost	Cost/A	Approximate % residual activity 30 days after last treatment(s)[y]	Acres/ man/ 30 days
1. Hand bait Zn_2P_3 apple[z]	4[x]	$12.00	$1.00	$ 6.00	$19.00	50-70%	60
2. Hand bait RH 787 apple, ICI 581	2[x]	6.00	1.00	w		0-5%	120
3. Hand bait - CPN-Rozol[z]	3.5[x]	10.50	1.00	14.00	25.00	0-10%	68
4. Hand bait - DPN-Ramik[z]	3.5[x]	10.50	1.00	14.00	25.50	0-20%	68
5. Ground sprayed CPN (0.2 lb/A)	.40	1.20	4.00	32.00	37.20	0-25%	600
6. Ground sprayed Endrin (2.4 lb/A)	.40	1.20	4.00	10.00	15.20	0-70%	600
7. Smitty Tree Hoe + herbicide (July & November)	2.00	3.00	15.00	herbicide 5.00	26.00	10-60%	480

[z] Two hand placement applications of 10 lb/A each applied from Oct 1 - Dec 31 at 30-60 day intervals.

[y] Control method effectiveness is dependent on ground cover, pesticide resistant pine vole populations (Endrin), application techniques, timing, weather, tree age, cultural management, and other factors.

[x] Labor requirements may be reduced by 1/3 with the use of a site cover weighing 2-4 lb covering an area of at least 825 sq. inches/tree.

[w] Price not yet determined.