Pine Vole Control with Anticoagulant Baits

Ross E. Byers and R. S. Young

Virginia Polytechnic Institute and State University, Winchester Fruit Research Laboratory, Winchester

Abstract. Hand placement of 2-Diphenylacetyl-1,3-indandione (Diphacinone, DPN) and [(choloro-4-phenyl)-1-phenyl-1] acetyldioxo-1-indane (Chlorophacinone, CPN) baits applied in 2 applications at 30 day intervals at 11.2 kg/ha (10 lbs/A) each were effective in the control of pine voles (Microtus pinetorum LeConte) in apple orchards. In a cultural experiment designed to control pine voles, one Diphacinone preparation gave near 100% control with one application in plots previously cultivated and treated with residual herbicide in July and November.

Post-harvest applications of hexachloroexoxyoctyhydroendo, endo-dimethano-naphthalene (Endrin) to the ground cover have been the major methods of pine vole control in orchards of the Central-Eastern United States for the last 15-20 years (5, 6, 7, 8). The effectiveness of Endrin in recent years has dwindled due to the development of Endrin-resistant strains of pine voles (10), and many fruit growers have returned to hand baiting procedures developed in the 1930s. Presently, zinc phosphate (Zn3P2)-treated grains are the only prepared baits available and cleared for use by the Environmental Protection Agency for orchard vole control. The reason for the relative ineffectiveness of hand baits has not been well established, but may be due in part to poor vole acceptance of the toxicant, carriers used (grain), poor distribution of baits throughout the underground range of the vole colony, and deterioration of the baits in the environment (4, 7).

Since acceptance of anticoagulant toxicants by rats has been well established (9), this study was initiated to determine if anticoagulant baits and techniques could be developed for orchard pine vole control. Previous experiments indicated that apple cubes treated with Chlorophacinone (CPN) applied by hand in runways and holes at rates from 11.2 to 50 kg/ha (10.45 lbs/A) did not give adequate control (1). and single applications of prepared baits of CPN and Diphacinone (DPN) also were not sufficiently effective. However, a double application of a CPN prepared bait applied at 11.2 kg/ha at a 42-day interval in one test gave excellent control (1) and provided the basis for the experiments presented.

Materials and Methods

The apple activity method developed by Horsfall (6) was used in 71 plots during 1972, 1973, and 1974 involving numerous treatments in 9 orchards in 4 states. These plots were exhaustively trapped immediately after the last activity reading and a regression analysis of the last activity reading and voles trapped per site is presented. An arcsine percentage transformation was performed on the data before analysis.

Experiment 1. An apple orchard with uniform terrain and tree stand was selected near Winchester, VA, where pine vole tunnel systems were evident under most trees. Each plot consisted of 36 trees (7 trees long and 8 rows wide) with the interior 12 trees used for the data collection and trapping. This plot design allowed 2 border rows between rows and 2 border trees between plots within rows. Prior to treatment of each 36-tree plot 2 activity sites were established at each of the interior 12 trees. Activity sites were established by selecting the most active runs or holes within the drip line of the tree, at least 3 m apart, preferably on opposite sides of the tree trunk and covered with a plastic trash can lid. An apple with ca 3 to 4 cm removed from the cheek was placed at each site and covered. After 24 hr 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 hemisphere of 2.5 cm removed by the voles. Percent activity referred to percent of apples with vole tooth marks 24 hr after placement. All plots were then exhaustively trapped (11/11-19/74) to determine the ca number of voles feeding at each site and to provide a second measure of the treatment effect. Three replicates for each of 10 treatments were randomized in blocks. An arcsine transformation was performed on percentage data prior to Duncan's multiple range tests however, data presented in Table 1 are the average percentage of 3 replicates. Various commercial bait preparations were applied at 11.2 kg/ha or 22.4 kg/ha on 9/24-26 and treated again at 11.2 kg/ha on 10/21 23/74. Bait preparations were provided by the Velasco Chemical Co. (Ramik), the Chemper Chemical Co. (Rozol), and the Archim Chemical Co. (Rodere and Finis). The Ramick-Red preparation was meat flavored and the Ramick-Brown preparation was apple flavored.

Experiment 2. A cultural experiment designed to control pine vole populations without the use of toxicants was initiated in an apple orchard at the West Virginia University Experiment Farm, Kearneysville, West Virginia in July of 1974. Trestments were 1) mowed control; 2) cultivation plus a residual herbicide, simazine at 2.24 kg/ha (2 lbs/acre) a.i., applied in July and November; 3) cultivation in November; 4) cultivation in July and November; and 5) herbicide combination of simazine 4.49 kg/ha (4 lbs/acre) a.i., dalapon 5.6 kg/ha (5.0 lbs/acre) a.i., and 2,4-D 2.24 kg/ha (2.0 lbs/acre) a.i. applied in July. Cultivations were performed with a Smitty Tree Hoe and residual and contact herbicides were applied to create a bare-ground strip 3.5 m wide. Plots were arranged in a randomized complete block design with 3 replicates. By late November activity readings indicated that none of the treatments was adequate to control the voles and all plots were uniformly treated on 11/28/74 with the

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2. Department of Horticulture, Virginia Polytechnic Institute and State University, Winchester Fruit Research Laboratory, and Division of Plant Science, West Virginia University, University Experiment Farm, Kearneysville, respectively.


Ramik-Brown (.005% DPN) preparation at 11.2 kg/ha. A second application was not made so that sufficient numbers of voles would reside in the area for repopulation of the plots.

Experiment 3. Another cultural experiment was conducted in a 14-year-old orchard near Batesville, Virginia (2). The Smitty Tree Hoe was used to cultivate 3 replicate plots of 40-45 trees each (ca 6 rows wide and 7 trees long). Comparison was made to 3 replicates of an uncultivated control where normal orchard practices were followed. Cultivations were performed May 8, July 2, and Nov 21, 1973. In the fall of 1974 the orchard was leased to a second grower, and the peach orchard adjoining the plot area was cultivated in October. Voles were seen moving down the hill into the plot area during the cultivation. In November, 1974, the 3 previously cultivated plots were cultivated, and in December all plots were treated with a double application of CPN (Rozol) wax pelleted bait at the rate of 11.2 kg/ha (10 lbs/A) each.

Experiment 4. Vertical boom ground cover spray applications of Endrin and CPN were made to 2 sections of an orchard involving ca 1.41 ha (3.5 acre) each on November 9, 1974. This orchard had been sprayed annually with Endrin for over 10 years. Activity was monitored over a period of 4 months in each section. Prior to treatment 40 activity sites were established in each section with a maximum of one per tree and only at those trees with easily found trail systems. Since Endrin did not give adequate control of pine voles, both plots were treated with hand placed baits, CPN and DPN at 11.2 kg/ha (10 lbs/A), on February 20, 1975.

Results and Discussion

The quadratic regression equation of percent active sites on voles trapped per site in 71 plots conducted in 1971, 1972, and 1973 was $y = 14.14 + 50.53 x + 7.38 x^2$, and had a coefficient of determination ($R^2$) of .72 (Fig. 1). The data suggest that the apple activity method may be used to approximate the trapable population and was used to monitor treatment effects over a long period of time without disturbing the population by trapping techniques as is the case with the North American Census of Small Mammals (NACSM) method (3).

Our preliminary studies on bait sizes indicated that baits weighing ca 0.2-5.0 g were redistributed by pine voles to underground storage caches generally near the nest site. Baits over ca 15 g were not easily carried through the tunnel system.

![Fig. 1. Regression of percent active sites on voles/site in experimental plots conducted in 4 states in 3 years.](image1)

![Fig. 2. Effect of apple orchard culture and Diphacinone (Ramik-Brown) hand baits on pine vole activity.](image2)

Table 1. Effect of caching hand baits on pine vole activity in an apple orchard (1974).

<table>
<thead>
<tr>
<th>Treatment*</th>
<th>Rate lb/A</th>
<th>Date 1974</th>
<th>% High activity*</th>
<th>% Activity</th>
<th>Voles/plot (11/11/74)</th>
<th>% of check trapped</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Check</td>
<td>10</td>
<td>9/24</td>
<td>83a</td>
<td>86a</td>
<td>37.7a</td>
<td>100.0</td>
</tr>
<tr>
<td>2. Ramik-Brown</td>
<td>10</td>
<td>9/24</td>
<td>84ab</td>
<td>86a</td>
<td>73a</td>
<td>69a</td>
</tr>
<tr>
<td>0.05% DPN</td>
<td>10</td>
<td>10/11</td>
<td>68a</td>
<td>13b</td>
<td>59a</td>
<td>44a</td>
</tr>
<tr>
<td>3. Ramik-Brown</td>
<td>20</td>
<td>9/24</td>
<td>61a</td>
<td>26b</td>
<td>59a</td>
<td>44a</td>
</tr>
<tr>
<td>0.05% CPN</td>
<td>10</td>
<td>10/18</td>
<td>59a</td>
<td>25b</td>
<td>59a</td>
<td>44a</td>
</tr>
<tr>
<td>4. Ramik-Red</td>
<td>10</td>
<td>9/24</td>
<td>59a</td>
<td>25b</td>
<td>59a</td>
<td>44a</td>
</tr>
<tr>
<td>0.005% DPN</td>
<td>10</td>
<td>10/21</td>
<td>61a</td>
<td>25b</td>
<td>59a</td>
<td>44a</td>
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<tr>
<td>5. Ramik-Red</td>
<td>20</td>
<td>9/24</td>
<td>59a</td>
<td>25b</td>
<td>59a</td>
<td>44a</td>
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<tr>
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<td>10</td>
<td>10/18</td>
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<td>25b</td>
<td>59a</td>
<td>44a</td>
</tr>
<tr>
<td>6. Ramik-Red</td>
<td>20</td>
<td>9/24</td>
<td>61a</td>
<td>25b</td>
<td>59a</td>
<td>44a</td>
</tr>
<tr>
<td>0.005% DPN</td>
<td>10</td>
<td>10/21</td>
<td>61a</td>
<td>25b</td>
<td>59a</td>
<td>44a</td>
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<td>7. Rozol</td>
<td>10</td>
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<td>61a</td>
<td>25b</td>
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<tr>
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<td>8. Rozol</td>
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<td>9/24</td>
<td>61a</td>
<td>25b</td>
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<td>10/21</td>
<td>61a</td>
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<td>44a</td>
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<td>9. Rodite</td>
<td>10</td>
<td>9/24</td>
<td>61a</td>
<td>25b</td>
<td>59a</td>
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<tr>
<td>0.005% CPN</td>
<td>10</td>
<td>10/21</td>
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<td>25b</td>
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<td>10. Finis</td>
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<td>61a</td>
<td>25b</td>
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<tr>
<td>0.005% DPN</td>
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<td>10/21</td>
<td>61a</td>
<td>25b</td>
<td>59a</td>
<td>44a</td>
</tr>
</tbody>
</table>

* Apples placed in 2 holes or runs located 15 cm below the soil surface on opposite sides of the tree trunk were examined 24 hr after placement. Percent high activity refers to a portion of apples with a semi-sphere larger than 2.5 cm removed from the apple. Percent activity refers to all sites with vole tooth marks on apple.

* Mean separation, within columns by Duncan's multiple range test. %.

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Experiment 1. All baits listed in Table 1 were in the size range required for redistribution by pine voles. All anticoagulant bait treatments significantly reduced the number of voles per plot (Table 1). Most of the treatments were different from the untreated control at the 5% level based on the apple activity method (Table 1). Terminal trapping of the plots gave more significant differences between treatments than the activity method. However, the activity method was not terminal and gave a better view of the percent of trees with at least one vole existing in the area. Detection of the presence of voles in the tunnel system with the activity method reflected the potential for repopulation through reproduction and provided a method for monitoring the treatment effects over a time period. Each method of measurement was valuable and strengthened the reliability of the other.

Experiment 2. One application of DPN (Ramik-Brown, .005%) applied to all plots (including the control) under different cultural systems did an adequate job of reducing vole activity to ca 20-30% (Fig. 2), however, under normal orchard management a second application would have been required. The cultivation-herbicide treatment subsequently treated with DPN hand baits significantly reduced vole activity to zero. This type culture reduced the number of hand bait applications required per year from 2 to 1. These plots were not terminated by trapping so that further study of culture-toxicant interactions with time could be determined. Complete girdling of trees occurred in February to 4 trees and 2 trees, respectively, in 2 replicates of the control plots even though they had been treated once with DPN in January. No trees in any of the cultural treatments were damaged at the trunk. Perhaps the cultural treatments caused sufficient dispersion of voles to prevent damage. These data also indicate the necessity of a double baiting procedure, especially in orchards not under cultivation.

Experiment 3. Two applications of CPN (Rozol) hand baits at 11.2 kg/ha (10 lbs/A) in December 1974 gave excellent control of the voles in both the cultivated and uncultivated plots (Fig. 3). The Smitty Tree Hoe cultivation treatments provided sufficient pine vole control without toxicants in the 1973-74 winter. Since pine voles damaged some trees in the uncultivated plots in the winter of 1973-74, all plots were treated with CPN hand placed baits in the fall of 1974. We believe the Smitty Tree Hoe effect was much enhanced in this experiment due to the semi-abandoned condition of the plot area. This orchard was sprayed very few times for other orchard pests, was not mowed or fertilized in 1974, and a number of snakes were removed from the activity sites in this experiment. In other properly mowed and sprayed orchards, we have never found snakes at our activity sites.

Experiment 4. Endrin did not have a measurable effect on the population; however, CPN applied at 0.224 kg/ha (0.2 lb/acre) did control the voles (Fig. 4). Since Webb and Horsfall (10) found that annual use of Endrin for over 10 years may lead to the development of resistant pine vole strains, we suspect that this difference was due to an Endrin resistant population and not to inadequate ground cover diversity. Both plots were treated with hand baits in February and excellent late winter control was achieved.

The hand placement of anticoagulant bait preparations tested in these experiments gave excellent control of pine voles when applied in 2 applications of 11.2 kg/ha (10 lbs/A) each and spaced at ca 30 day intervals. Whereas ground cover sprays can only be used during a short period after harvest (1, 6, 8), these hand placed baits were effective during all periods tested from September through February. Further, the combination of cultivation and herbicide orchard culture was found to reduce the number of bait applications required. Considerably more effort will be required to determine if a change in culture will provide a completely non-toxicant control method.

Literature Cited

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Artificial Lighting and Spacing as Photosynthetic and Yield Factors in Winter Greenhouse Tomato Culture

B. P. Rodriguez and V. N. Lambeth

University of Missouri, Columbia

Abstract. Photosynthetic and yield responses of tomato, Lycopersicon esculentum L., cv. Tuckcross V and Tuckcross 533 supplemental lighting and spacing were studied during the unusually dark winter of 1972-73. Supplemental lighting and wide spacing increased total flowers, fruit set, fruit size, and total fruits/plant, and contributed to greater early and total fruit yields. The increases were related to increased apparent photosynthetic rate and efficiency. Supplemental top lighting (184 W/m²) increased fruit weight/plant 1107 g/plant (89%) over natural lighting for an increase of 6.0 g/plant for each watt/m². Supplem­mental top + side lighting (368 W/m²) increased fruit weight 2853 g/plant (121%), an increase of 7.7 g/plant for each watt/m².

Maximum fruit yield/plant was obtained with top + side lighting at a spacing of 50.8 x 41 cm in a staggered double row bed. Plant spacing of 38.1 x 41 cm with maximum lighting gave greatest yield/unit area. Photosaturation was not attained by supplementary lighting.

Light energy generates the photosynthetic process in plants and is one of the most critical determinants of crop yield. In winter, when light duration is short and intensity low, light often becomes the limiting factor in greenhouse tomato production. General growth and yield responses of tomato to artificial illumination have been reported. Greatest dry wt of tomato seedlings was produced under artificial light (12, 13). Decrease in light intensity increased internodal length of normal and dwarf tomatoes (5). Tomato yield and quality decreased gradually with light at each successive harvest of a fall crop and increased with light at successive harvests of a spring crop (1). Illumination at an early stage of development accelerated the yield and resulted in normal growth of ovules and fruits (10). Shading reduced yield and increased the proportion of misshapen fruits with or without hand pollination (6).

Maturity was hastened by supplemental lighting (11).

The levels of greenhouse lighting and the concomitant effect of plant spacing and cultivar interaction on photosynthetic rate and yield at different lighting levels are largely undetermined. Due to the inherent habit of growth, shading of lower leaves may occur even to the point where they become parasitic on photosynthetic reserves. Under low light conditions and intense interplant competition, yield may be greatly augmented by artificial illumination.

We determined yield response to varying levels and orientation of supplemental lighting; established possible interactions of lighting level, cultivar and spacing; and measured apparent rates and efficiencies of photosynthesis as affected by these variables.

Materials and Methods

Seeds of ‘Tuckcross V’ and ‘Tuckcross 533’ were shown October 2, 1972, transplanted in the greenhouse November 19, 1972.

The Cornell ring culture method was used (8). One plant was transplanted to each 20 x 30 cm ring and the rings were set in 7 x 1 m wooden troughs lined with polyethylene film. Rings and troughs were filled with Cornell peat-lite growing medium (7). The plants were trained to overhanging wires set horizontally above the troughs.

Supplemental lighting (L), cultivar (CV), and plant spacing (S) treatments were studied in a split-split plot design with 4 replications, replicated within light treatment blocks. The experimental space was divided into 3 lighting units (L1, natural light; L2, 6 lamps; L3, 12 lamps) separated by a curtain of black polyethylene film. Each lighting unit consisted of 2 troughs, one for each cultivar. The troughs were further subdivided into 3 staggered double-row spacing groups within cultivar. Four plants represented a replicate for a total of 52 plants per lighting unit, including buffer plants.

Supplemental lighting was provided by twin 244-cm, 215-watt, wide-spectrum Sylvania Gro-Lux lamps (FR9T12/GRO/VHO/WS series) mounted 45.72 cm apart in a metal fixture. The L2 treatment consisted of 3 lighting fixtures (6 lamps) placed end to end and maintained about 30 cm above the plant tips. The 6 lamps provided 184 W/m² (17.09 W/ft²) of greenhouse floor area. In the L3 treatment, 3 lighting fixtures were oriented above the troughs as in L2 and 3 additional fixtures (12 lamps total) were slanted at the side and maintained half-way between ground level and the plant tips, and 30 cm from the plants. The 12 lamps provided 368 W/m² (34.19 W/ft²) light. The lights were on during the day to conform with natural daylength for the period November 19, 1972 to April 14, 1973.

Photosynthetic response was measured by the radioactive ¹⁴CO₂ technique. Brief pulses of ¹³CO₂-labeled air were introduced over an enclosed area of the leaf and ¹⁴CO₂ uptake was measured by radioactive count from the exposed area. The technique was principally that of Shimshi (9) with the following modifications: the final CO₂ concentration of the labeled air was determined by repeated titration of the ¹⁴C-stock solution; the leaf samples were oxidized in a Packard Model 305 Tri Carb Sample Oxidizer; and 1.02 was used as the discrimination factor against ¹³CO₂ (14). Photosynthetic measurements were made 4 times; twice, each, during a cloudy day (90 110