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ABSTRACT

The meadow vole (Microtus pennsylvanicus) and pine vole (M. pinetorum) are major pests in fruit orchards in the eastern U.S. These species damage trees by gnawing the bark or root systems during the winter months, thus, reducing the fruit yield, or in many cases actually killing the trees. Orchard owners generally use an integrated pest management approach involving a combination of methods: (1) cultural practices such as reducing favorable vole habitat, thereby, limiting the carrying capacity, (2) mechanical control through the use of tree guards or trapping techniques, and (3) the use of rodenticides, both acute and chronic. Economics, or affordability, is often the determining factor as to which method or methods an orchard manager will utilize to reduce vole damage to trees. Although rodenticides offer an effective means of control, the use of chemicals should be in combination with either cultural or mechanical control measures. Environmental considerations are of utmost importance in the chemical control of voles. Both primary and secondary hazard potential to non-target wildlife should be examined before a product is used. The rapid environmental degradation time of certain compounds reduces exposure to wildlife.

INTRODUCTION

Voles of the genus Microtus have been studied for years because of their periodic cycles in density and resultant outbreaks. Fifteen species are known from North America, of which the pine vole and meadow vole are of major economic importance in the eastern U.S.

Pine and meadow voles are pests in both fruit orchards and forest nurseries. They damage trees by gnawing the phloem and cambium layers from the main stem or trunk and by feeding on the root systems. An overview of the current vole situation in the U.S. is presented by Byers (1984). Apart from damage to fruit trees such as apple, pear, peach and cherry, voles also damage vegetable crops including carrots, potatoes and peanuts. Alfalfa is also a favorite target of voles since the legume provides dense cover and abundant food supply for the small mammal.

The degree of vole damage on a large scale is difficult to ascertain, since damage is often only recorded by the evidence of dead trees. Pine voles, for example, feed extensively on the root systems which causes trauma and the resultant loss of tree vigor. Such yield loss is difficult to quantify.

Sullivan et al (1980) in a survey of vole damage in North Carolina orchards, reported a 0.5% of apple tree mortality was a direct result of voles. In a nationwide survey of apple growers, Ferguson (1980) revealed that each year about 123,000 trees are lost of which 37% suffered vole damage. Anthony and Fisher (1977) reported about $270,000 was spent in Pennsylvania on pine and meadow vole control in 1974. LaVoie and Teitjen (1978) revealed pine vole damage resulting in apple orchard losses of approximately $50 million in 1978.

Damage by voles to apple trees generally takes place in the winter months or dormant season. As native grasses and forbes dry out and the food supply is reduced, voles will feed on the trees.

Meadow voles are more of a surface dwelling species and rely on trails or runways as opposed to pine voles which are more subterranean in habit. Meadow voles are more prone to attack the tree trunk above ground level, whereas, pine voles damage the trunk beneath the soil surface, frequently feeding on the roots.

Meadow voles, as a result of behavior, have larger home ranges. In winter, the home range is reduced and movements are more localized (Madison 1984). Control of the species in a limited area, such as only an orchard, may result in quick re-invasion by voles from outlying areas. Miller and Richmond (1982) reported on

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the results of a field trial in which the vole population was reduced to near zero in one orchard. Within one year, *movements* into the available habitat by voles from bordering untreated land, resulted in a population level nearly equivalent to that observed before treatment.

Pine voles, because of their more forrorial habits, are difficult to control. Although there may appear to be little or no surface vole activity of pine voles, in North Carolina, as an example, voles were reported to kill 41% of all dead apple trees (Sullivan et al 1980). The remainder of trees died from disease or injury. If left unchecked, a pine vole population can virtually destroy an orchard over a period of several years.

A number of techniques have been proposed to apple growers to monitor vole numbers (see Davis 1976; Hayne and Sullivan 1980). The methods may involve prodding or raking beneath trees for rodent signs, using untreated census baits, live or snap traps, pitfalls, or a survey of tree damage. Byers (1975) developed the "apple index" which monitors the presence or absence of mice, evidenced by the gnawing on apple slices placed near the base of the tree. Unfortunately, it is not possible to use a single technique since there are many variable differing with the species, orchard type, and region of the country. The general concensus remains that if the immediate area beneath 10% of the trees show vole activity, the potential for severe damage is highly probable.

CONTROL STRATEGY

According to Byers (1984), vole control involves numerous considerations, including: the effectiveness and cost of the method(s), its integration with other orchard management practices, the potential hazard to man and non-target animals, equipment, labor, management required, and the availability of chemical products.

The economic threshold for voles is low since a single vole can inflict significant damage or tree loss. Therefore, an effective and reliable preventative program is required to avert damage of perennial tree crops (Byers 1984). Careful monitoring of populations is essential since the presence of voles is more than often indicated by visual evidence of damage. The abundance of food supply, however, does not preclude damage. Often voles will nest next to the base of fruit trees and since their winter movements are reduced will tend to feed on the tree (Fitzgerald and Madison 1981; Madison 1980).

MANAGEMENT METHODS

The main objective of vole management is to increase fruit production through the reduction of tree damage. As with any wildlife problem, a key to vole management involves determining the density of animals per unit area. This is followed by an examination of the environmental parameters that trigger an increase in vole numbers. Control then involves a disruption in these factors which should attain the desired lower population density.

Although techniques such as resistant rootstocks, the use of hoofed animals, predators and microorganisms have potential, they have yet to be perfected to ensure effective vole management. The two major management schemes used today involve either cultural or chemical control methods or a combination of both.

Cultural Management

An objective of orchard management involves the reduction of vole numbers by way of lowering the carrying capacity in a given area. Voles perfer dense ground cover as ideal habitat. The use of herbicides or vegetation removal (such as discing) in orchards can have great potential in preventing voles from establishing burrow systems. Often various forms of cultivation are used to chop up surface litter, which may provide more suitable habitat, therefore, the control of vegetative production may aid in reducing vole numbers. More specifically, a study by Byers and Young (1978) demonstrated that two cultivations, in July and November, along with residual herbicide treatments resulted in lower vole numbers. Today, however, the cost of most forms of cultural management are too expensive to fully exploit.

An important factor to remember is that although vole numbers may be lowered through cultural practices, a residual population may be sufficient to inflict significant tree damage.

Horsfall et al (1974) advocated planting orchard vegetation in which mixed forbs are dominant over grass. This provides a more varied food supply for voles and tends to reduce tree damage. Fruit trees are normally not the main source of nourishment of voles, but the small mammals prefer roots, stems, and petioles of a diversity of plants on or below the soil surface (Cengel et al 1978).

As Byers (1984) noted that in the past, clean culture within orchards meant the complete removal of vegetation. Today, however, the trend has been to use a combination of mowing and herbicide sprays. Strips are mowed between tree rows and herbicide sprayed around the base of each tree to remove vegetation. This type of practice may be of particular importance in young orchards before voles are established.

Mechanical Control

In the past, vole trapping was considered as a possibility to control numbers. However, the expense for such a program has made the technique cost prohibitive. Byers (1981) noted that voles were more susceptible to trapping if conducted in the fall and late winter. Frantz and Padula (1983) reported glue boards or tubes have a possibility for vole control. Maintenance of the equipment would be expensive and not always effective.

Tree guards consisting of wire or plastic have been used extensively in the fruit industry (Radvanyi 1974). These are placed around the young seedling and generally are designed to protect the bark above ground. Thus, voles can burrow under the guard or, as in the case of pine voles, feed on the roots. In surveying orchards in New York State, tree guards too were observed to be effective in reducing meadow vole damage to young trees. In a mixed vole species habitat, however, the benefits would be less practical.

Rodenticides

A survey of apple producers was conducted by Ferguson (1980) as to the satisfaction with available vole control methods. About 15% of the growers felt that mowing and cultivating were effective, 18% reported that mechanical methods (such as tree guards) were good, and approximately 58% felt rodenticides were the most effective means of control. These figures varied among regions. The rodenticide products included zinc phosphide, diphacinone, endrin and chlorophacinone.

Of the products used in the U.S., the study by Ferguson (1980) reported that of the one-half million acres under apple production, rodenticides were used for vole control in 28-78% of the total acreage. Of this amount, approximately 18% used was endrin, 31% Ramik (diphacinone), 10.5% Rozol (chlorophacinone), 39% zinc phosphide and 8% warfarin and strychnine baits and chlorophacinone ground spray. Today endrin is no longer used for vole control.

Rodenticide baits are registered with the Environmental Protection Agency generally for hand, bait station, broadcast, or aerial applications. Rates vary from 4 to 15lbs per acre depending on the product and infestation level.

Rodenticides are available as pelleted baits (e.g. 3/16th inch), cracked cereals, or sprays. Often a single application is required, but for less toxic baits or lower application rates several applications may be necessary.

Numerous studies have been completed comparing the efficacy or effectiveness of vole population reduction for various products available on the market. Hood (1972) described the ideal rodenticide as having the following characteristics: (1) well accepted by the target species, (2) safe to minimize non-target hazards, (3) safe for humans to handle, (4) no genetic resistance in rodents, (5) slow acting to minimize bait shyness, (6) generates a painless and nonviolent death, (7) non-bioaccumalative, (8) does not translocate in plants, (9) degrades into harmless by-products, (10) has an effective antidote, (11) economical to manufacture and apply, and (12) can be registered with the EPA.

As Kaukeinen (1982) states, that while such properties are probably impossible to ever satisfy in entirety, they remain desirable goals, and a means by which to compare various toxicants.

To the orchard grower, the economics of control are important considerations in vole management. Table 1 lists the costs for several chronic rodenticide studies. These costs include labor, mowing, herbicide, and rodenticide applications.

	Source	
Product	Pagano and McAninch (1983)	Byers (1983)
Rozol	$17.86	$20.41
Maki	21.84	
Laqberry	31.91	
Volid	44.77	10.29
Ramik	27.64	40.82

Table 1. Vole control expenses with chronic rodenticides in two studies are listed from the eastern U.S.

Data from Byers (1983) with Rozol indicated the cost for control was $20.41 per acre. Using these data in combination with a study completed by Richmond et al (1983) on projected vole-induced apple loss, the cost/benefit ratio can by approximated. Considering a 100 acre orchard with medium vole damage would result in a projected crop loss amounting to about $14,300. This would indicate that for each $1 invested in vole control, the return in terms of crop saved, would be approximately $7.

Numerous published studies presented data on vole population responses to rodenticide treatment. For example see Byers (1978), Byers et al (1982) and Steblein and Richmond (1982).

The method of application, timing, and cover type should be similar on study plots which try to compare efficacy of different products. With regard to the use of acute rodenticides, such as zinc phosphide, mortality is induced within hours and significant reduction in vole numbers can be observed within one day. For chronic baits, however, the response is slower and the average time until death after ingestion of a lethal dose is about seven days.

Chronic rodenticides have the advantage of eliminating the potential for bait shyness. Although it has not been shown in orchards, acute baits tend to induce an aversion response in rodents if used for an extended period of time.

An ideal system for vole control would involve a combination of acute and chronic products. The acute bait will reduce the population rather quickly, while the chronic bait will provide long-term maintenance. To date, however, most chronic products used for vole control are registered under Special Local Needs permits within different states and have not been granted full registration by the U.S. Environmental Protection Agency.

ENVIRONMENTAL CONSIDERATIONS

Pesticide registration is required before a rodenticide can be applied in the field. This process entails a list of chemistry requirements, details on the synthesis, analytical methods, toxicity studies on rodents, fish, birds, invertebrates and other wildlife, human safety (inhalation, dermal toxicity, occular testing), environmental fate (photolysis, hydrolysis, absorption and adsorption, aerobic and anerobic microbial decomposition),metabolism, and a series of laboratory and field efficacy studies. The investment to register a new active ingredient today, lies in the range of $5-7 million, depending on the proposed use pattern.

For this reason, researchers and manufacturers are taking a more careful look at existing registered compounds. The U.S. Fish & Wildlife Services, for example, completed a study during 1984 using lower dose levels of compound 1080 to control prairie dogs (P. Hegdal, per comm.). The results proved effecttive, with little in terms of non-target hazard potential. As previously reported, higher dose levels of compound 1080 were considered dangerous for non-target wildlife,such as bobcats and coyotes (Hegdal et al 1981), Strychnine has also been noted as a product that is considered in the range of the high risk group, especially in bird-induced mortality.

Zinc phosphide has a relatively clean record in term of non-target hazards. For this reason, the U.S. Department of the Interior secured registration for a 2% bait for prairie dog control (Tietjen 1976).

The usefullness of a rodenticide for field applications is not simply related to its chemical activity, or the ability to kill a target species. The development of chronic rodenticides in the late 1940's resulted in the rapid evolution of rodent control techniques. This process is ongoing and, unfortunately, the answers are not always discernible over a short time period. Molecular structures were developed to address resistance in rats and mice to the coumarin compounds.

The awareness of rodent depredations in agriculture has stimulated both industry and governments to attain efficient and safe means of rodent control, especially in the field (e.g. Poché et al 1982).

Evans and Ward (1967) discussed the hazard potentials of warfarin and diphacinone to non-target vertebrate species. The toxicity of other rodenticides, especially brodifacoum, to voles was reported by Mendenhall and Pank (1980). Hegdal and Blaskiewicz (1984) reported on how barn owls (Tyto alba) fed extensively on voles, while Merson et al (1984) presented tissue residue data from screech owl (Otus asio) research with brodifacoum. The specific activity of a compound is often consistant in rats, fish and wildlife. Table 2 presents toxicity data on several chronic compounds used in the U.S. for rodent control.

Published data are not available on the toxicity of compounds, such as diphacinone, to fish and wildlife. It is probable that the EPA will require data from rodenticides marketed in the U.S. before the federal requirements for registration were issued in 1972 and 1974.

The potential overall impact of rodenticides to non-target wildlife is not related only to the fact that one compound is more active than another. Other important concerns include the potential for bio-accumulation and persistence in tissues, the half-life in blood and tissues, and its fate in the environment as a result of sunlight, temperature and humidity, or binding potential.

Increased interest has been generated towards and old compound - Rozol or chlorophacinone. Studies by Horsfall et al (1974) demonstrated that when the rodenticide was used at high concentrations (0.2% a.i.) for vole control in orchards, the material did not translocate in to apples. This is true for most chronic rodenticides, since most are virtually insoluble in water. In addition, no chlorophacinone was de--tected in runoff, and after 30 days no residue was detected on plants sprayed with the product.

Figure 1 presents interesting data on chlorophacinone. The combined results from Byers (1981) on the time required to control a vole population and a study of field degradation of the product (Lechevin 1979) are plotted on the same graph. These data show that as the vole population declined in numbers, the amount of active ingredient in the bait would have decreased also. Chlorophacinone is sensitive to ultraviolet light and degrades rapidly on grain baits. This has an advantage by reducing the possibility of prolonged exposure of the rodenticide to the environment. Although a hazard potential exists for all products when used incorrectly, chlorophacinone may tend to have an advantage in its potential for rapid degradation. More detailed studies are programmed in this area.

Vole control in the U.S., requires the use of cultural, mechanical, and/or rodenticide control measures. These offer potential for reducing economic losses in the fruit orchard and tree nursery industries. The key to efficient vole population reduction lies in the planning and implementation of an effective method of application. Factors such as the costs of mowing, cultivation, placement of tree guards, and purchase of rodenticide products are important in determining the feasibility of control efforts. An array of toxicity factors should be examined before selecting a rodenticide product. A collaborative effort is required among the growers, industry, and state and federal agencies in promoting safe and effective vole control.

Species	Rodenticide	LD_{50}	LC_{50}	Reference
Pine Voles	Brodifacoum	0.36		Byers (1978)
	Bromadiolone	3.90		Byers (1978)
	Chlorophacinone	14.2		Byers (1978)
Mallards	Brodifacoum		2.7	Anon.
	Bromadiolone		110.0	Anon.
	Chlorophacinone		426.0	Anon.
Bobwhite Quail	Brodifaccum		0.80	Anon.
	Bromadiolone		62.00	Anon.
	Chlorophacinone		242.00	Anon.

Table 2. Comparative toxicity of several chronic rodenticides to the pine vole and two bird species are listed. Data are expressed in mg. of rodenticide to kg. of species body weight.

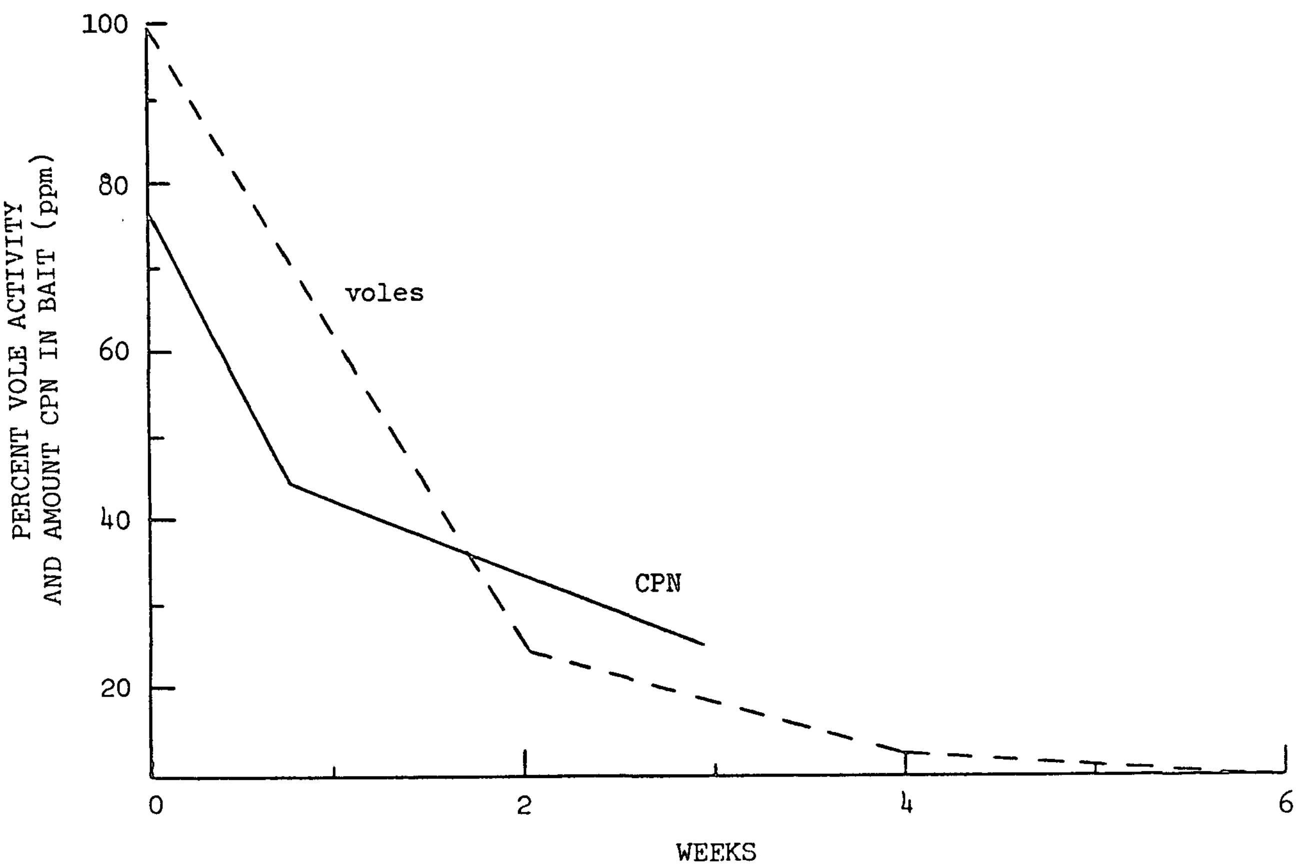

Fig. 1. The response of a vole population treated with Rozol (CPN) 50 ppm bait (-----) and the field degradation of CPN plotted over time.

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