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Abstract. Chemical methods were found to be less expensive for control of voles (Microtus spp.) in orchards than the use of clean culture (combinations of herbicides, mowing, and cultivation). Ground cover sprays of hexachloroepoxyoctahydro-endo-endo-dimethanaphthalene (Endrin) or 2-[(p-chlorophenyl) phenylacetyl-1,3-indandione (Chlorophacinone, CPN, Rozol) required greater equipment and pesticide costs than hand placed or broadcast baits. Since active ingredient rates for ground cover sprayed chemicals may be 100-400 times that for hand placement or broadcast baiting, the costs for any new ground spray will likely be too expensive to be practical. Broadcast baiting, while less labor intensive than hand baiting, was found to be as expensive as hand placement since larger quantities of bait were needed for treatments. The costs for broadcast or hand placed baiting were found to be less for acute toxicants, since the quantity of bait required for a lethal dose is less for acute baits.

Introduction

The rationale for the selection of a Microtus pinetorum LeConte and Microtus pennsylvanicus control method may be based on a multiplicity of reasons involving effectiveness, cost, integration with other orchard practices, hazard to man or non-target animals, and availability of labor, management, and equipment. This paper will discuss the economic inputs related to the control measures currently used for the control of Microtines in eastern U.S. orchards. The relative effectiveness of the control programs will not be discussed in detail except in relation to the selection of a control program.

Experimental Methods

The cost per hour for labor and orchard equipment (except for cultivation equipment) was taken from a report on orchard replanting costs (Gerling, 1981) (Table 1). Cultivation equipment costs were estimated from repair and purchase price of a Smitty tree hoe used in experiments (Byers and Young, 1978). The total cost for a control measure (pesticide, labor, and equipment costs) was taken from our work while conducting experiments using various control measures in local grower orchards (Byers, 1975, 1978, 1981, 1982 et al.; Byers and Young, 1978). One half rates of pesticides were used for hand placed baiting programs since an average of 50% of the bait stations had no runway and thus were not baited. Also, labor requirements were reduced 50% since the use of bait stations such as shingles or split tires greatly increased labor efficiency. Costs for labor at $6.00 per hour

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included the employer's share of social security, workmen's compensation insurance, and cash cost of any benefits. Herbicide materials were calculated for two Simazine applications if applied in conjunction with cultivation, or one application of Paraquat plus Simazine if no cultivation was used.

Results

A cost analysis of the current control measures for Microtus revealed that 'clean culture' (combinations of herbicides, mowing, and cultivation) and ground cover sprays were significantly more costly than broadcast or hand placement baiting programs (Table 2). Labor requirements were most costly for 'clean culture' and hand placement of bait while ground cover sprays and broadcast baits were least costly. Equipment requirements were least costly with hand placement and broadcast baiting. Pesticide costs were least expensive for hand placement of bait since lower quantities of bait may be used per unit of orchard area. Bait for single broadcast applications were less expensive than chemical for ground cover sprays. Costs for herbicides were substantial ($19.80/ha), however, if herbicides are applied for removal of weed competition, only a part of this cost should be charged against Microtus control. In this example all costs were charged to Microtus control (Table 2).

The economic threshold for damage by Microtus is at very low population levels. A single animal residing at a tree may cause sufficient damage to eliminate future production from the tree site for the productive life of the planting. Since the loss of a single 15-year-old tree's production in a 5-50 ha block may be equivalent to the cost of treatment, a highly effective preventive program is essential for eastern U.S. orchards.

The choice of a control method will firstly depend on its reliability and secondly upon its cost relative to other effective control methods. 'Clean culture' programs are recommended to remove weed competition and for promotion of tree growth in the early years of a planting; thus, bare soil strips within the row maintained with herbicides and close mowing in the middles may prevent the establishment of a Microtus population at no cost for vole control. However, once a Microtus population has become established little value can be realized from herbicide culture for Microtus pinetorum control (Byers, 1978). A program involving cultivation + herbicide + mowing program may reduce or eliminate the need for a rodenticide treatment but previous research has shown (Byers, 1978) additional rodenticide treatments may be necessary in many orchards. For this reason, 'clean culture' programs solely for vole control have not been popular and the expense may not be justified if rodenticide treatments are expected.

Some ground covers and leaf mulches make ground sprays (Horsfall et al., 1974) and/or broadcast baiting ineffective because the voles make their runway below the thatch layer and are shielded from the toxicant. In these cases, only hand placement of bait may provide reliable control.

Overall, the use of acute toxicants for hand placed or broadcast application methods are the least expensive. Ground cover sprays and

'clean culture' are much more expensive and, from a control point of view, have no advantage.

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Table 1. Constant values used for calculation of costs (1981).

Item	$ Cost/hr	Rodenticides	$ Cost/kg
		BAITS	
40 HP diesel tractor[z]	4.90	Brodifacoum	3.85
60 HP diesel tractor[z]	7.60	Chlorophacinone	2.20
Airblast sprayer[z]	11.95	Diphacinone	2.20
Weed sprayer[z]	3.80	Zinc Phosphide (ZP)	2.20
		Zinc Phosphide (others)	0.88
		GROUND SPRAYS	
Fertilizer spreader (3 pt)[z]	2.20	Endrin (liquid)	33.00
Rotary mower[z]	4.20	Chlorophacinone (liquid)	396.00
Smitty tree hoe[y]	7.10		
Pick-up[z]	6.25		
Labor[z]	6.00		

[z] Cost estimates are from Gerling, 1981.

[y] Costs were estimated from local grower information.

Table 2. Costs for Microtus control programs currently used in Eastern U. S. apple orchards (1981)[z].

Control method	Number of applications per year	Rate kg/ha	Man hours/ha	Labor Cost/ha	Equipment Cost/ha	Pesticide Cost/ha	Total Cost/ha	Approximate effectiveness of treatment (% population reduction)
HAND PLACED BAITING								
BFC-Volid	1	2[y]	2.5	15	0.65	3.85[y]	19.50	95-100
CPN-Rozol	1	11[y]	2.5	15	0.65	12.10	27.75	90-95
DPN-Ramik-Brown	2	22[y]	5.0	30	1.30	24.20	55.50	90-95
Zn_3P_2-ZP Rodent Bait	1	2[y]	2.5	15	0.65	2.20	17.82	85-95
Zn_3P_2-Other formulations	1	2[y]	2.5	15	0.65	.88	16.53	50-70
BROADCAST BAITING								
BFC-Volid	1	6	0.2	1.20	1.42	23.10	25.72	90-100
CPN-Rozol	1	22	0.2	1.20	1.42	48.40	51.02	90-100
DPN-Ramik-Brown	2	44	0.4	2.40	2.84	96.80	102.04	90-100
Zn_3P_2-ZP Rodent Bait	1	6	0.2	1.20	1.42	13.20	15.82	85-95
Zn_3P_2-Other formulations	1	6	0.2	1.20	1.42	5.28	7.90	50-70
GROUND COVER SPRAYS								
Endrin	1	2.5	0.8	4.80	19.55	82.50	106.85	0-95
CPN-Rozol	1	.21	0.8	4.80	19.55	83.20	107.55	40-95
CLEAN CULTURE								
A. Herbicide	1		2.0	12.00	17.40	19.80	49.20	0-100
B. Mowing (additional)	3		4.5	27.00	40.95	---	67.95	0-20
C. Cultivation	2		5.0	30.00	60.00	19.80	109.80	40-90
D. Cultivation + herbicide + mowing	2		8.0	48.00	87.30	19.80	155.10	60-90

(See next page for table footnotes.)

(Footnotes for Table 2)

[z] See Table 1 for constant values for labor and equipment.

[y] One bait station per tree was observed. Bait was placed at all active stations. Since approximately 50% of the stations were inactive, bait quantity placed were at one half rates/ha of column number 2. Labor costs would be at least double these costs if no bait station was used.

[x] Effectiveness of some treatments was questionable.