Proceedings of the 6th Vertebrate Pest Conference (1974)
Vertebrate Pest Conference Proceedings collection

March 1974

DUAL ROLE OF FORBS AND RODENTICIDES IN THE GROUND SPRAY CONTROL OF PINE MICE

Frank Horsfall Jr.
Virginia Polytechnic Institute and State University, Blacksburg, Virginia

R.E. Webb
Virginia Polytechnic Institute and State University, Blacksburg, Virginia

Ross E. Byers
Virginia Polytechnic Institute and State University, Blacksburg, Virginia

DUAL ROLE OF FORBS AND RODENTICIDES IN THE GROUND SPRAY CONTROL OF PINE MICE

FRANK HORSFALL, JR., R. E. WEBB, and ROSS E. BYERS, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

For the time being at least, theories espousing control extrinsic to ecological systems is not considered to be promising ---Pitelka.

ABSTRACT: Highly effective controls for the pine mouse (Pitymys pinetorum) were obtained for three years in apple orchards by means of herbaceous ground cover sprays of [(chloro 4 phenyl) 1 phenyl] acetyl 2 dioxo 1-3 indane at a rate of 0.2 lb. per acre of actual orchard. This toxicant from Europe is designated there as chlorophacinone. The spray residue persists for a maximum of about 30 days and was not found to be translocated to fruits nor was it detected in runoff water. Ingestion of the lethal agent is markedly enhanced by an adequate presence of forbs in the treated greenery. Too little attention has been directed to the basic differences in control between herbaceous type feeders and the seed consumers. CPN is now reported to give excellent results from large-scale applications by growers.

INTRODUCTION

Under conditions other than that fully satisfactory for rodenticidal spraying of herbaceous cover, pine mouse (Pitymys pinetorum) damage continues to be the number one cultural problem in many orchards along the Atlantic seaboard. The principal southwest to northeast geographical range of this target species is about 800 miles between north latitudes 34° and 44°

The three long continuing objectives of the lengthy investigation of pine mice have been, first--the mechanization of control; second, a prevention of tree damage rather than a kill-only goal; third, a study of the habitat and the life cycle. Only a small part of the total effort is here reported. Invaluable assistance to this study has been received from several sources.*

At present, state and federal regulations for the application of the important rodenticidal sprays as controls do not permit other than dormant season applications. On forb deficient sites, even with a 100% kill during the usual control period, reproduction and invasion in the following warm season can produce appreciable tree damage prior to the next post-harvest sprays of the orchard cover. We must face the inevitable fact that, within their geographical range, a few to many pine mice will infest the orchard all of the year. What is to be done about these continuing populations? During one full year under conditions of no pine mouse control, Horsfall (1963) found that the adult females exhibited a month to month variable from 13% in April to 72% gravidity rate in November. Similarly, Rhodes (1903) reported that pine mice bred all of the year. In two seasons, Valentine and Kirkpatrick (1970) did not capture gravid females for five months following November 1. In a case apparently somewhat similar to that of invading pine mice, Blair (1940) estimated that in July and August 12% of a meadow vole population was transient. In view of the foregoing, the writers have concluded that an essentially kill-only program is unlikely to attain the required prevention of tree injury. The herewith suggested system is one of population management with necessary adjunct of toxicant sprays that are applied on certain types of herbaceous ground cover.

In addition to the expected hazard from reinfestation during the first 12 post-treatment months, orchards are too frequently limited to one principal herbaceous forage which is likely to be a dominant grass. In their evolutionary past pine mice have become adapted to a habitat that provided a wide choice of forages. Apparently as a consequence, a strong preference for feed variety exists. Over the years since 1859, a number of authors collectively

*Grateful appreciation is extended to the Virginia Agricultural Foundation for the major funding that made the study continuation possible. Acknowledgement is made for the invaluable assistance of VPI & SU staff members, Dr. Myron Shear for the identification of herbaceous plants, Dr. C. Y. Kramer for the experimental designs and the statistical analysis of data, and Professor R. W. Young for the chemical analyses.

have listed as pine mouse feed a total of 76 species of plants that are distributed among 62 genera. Fourteen species are mentioned as being found in caches. It is self-evident that any successful population management among mammals requires some measure of attention to their life cycle and a possible simulation of their natural habitat. Horsfall et al. (1953) (1972) (1973) have given considerable study to the pine mouse way of life. Man's past short comings to adjust to the exigencies in relation to habitat have resulted in a high degree of control failure.

Under grassland conditions, highly acceptable feeds as naturally provided as in a sod orchard and even when somewhat restricted in variety are continuously at hand in immense quantity. At a probable herbivore carrying capacity of a 1000 lb. animal unit per acre, the orchard provides an enormous feed potential for the extremely few pounds of mice present. Appreciably unsatisfied hunger can hardly occur in any season even without the survival of trees. The usual rodent control assist by feed withdrawal, as for rats, is out of the question. The population management system must operate under conditions of a bountiful feed presence. Ultimately bait failures are almost assured by the persistent "hit and run" habit of sublethal small scale sampling of any discovered feed and then for the animal to move along the trail.

The manner of slight nibbling may quickly build up toxicant surviving bait-shy populations. Accordingly, with pine mice, it is not probable that baits can ever be more than a stop-gap procedure. With repeated use of any bait toxicant, the effectiveness of such baits declines more or less rapidly to near worthlessness as a tree protectant. When first employed in any orchard, zinc phosphide as the principal bait toxicant can approach the required control. Much too soon the action of this latter toxicant becomes weak or not at all effective. Accordingly at present, it is firmly believed that treating of a major portion of the native feed with a spray on herbaceous cover rather than spot baiting must continue as the basis of control in containing this target species. As of now the U. S. Fish and Wildlife Service has no bait type of control that it can recommend. It becomes clear that toxicant administration to pine mice presents aspects quite foreign from that for the seed or seed product consuming small mammals. The present research has been forced to break from conventional baiting procedures.

Toxicants

The present study, so far as is known to the writers, is the first attempt to employ chlorophacinone (CPN) [(Chloro 4 phenyl) 1 phenyl] acetyl 2 dioxo 1-3 indane, as an herbaceous cover spray for the control of pine mice. Commercially this material is also known as Liphadione in France and more recently as Rozol. By the use of baits in France, Grolleau (1971) reported that CPN appeared to be the single anticoagulant substance utilizable for the control of Microtus arvalis. Also from working with baits in Europe, Moens and Ghesquiere (1969) stated that the CPN treated area was thoroughly cleared of muskrats and that the favorable situation was maintained during the total ensuing winter. Horsfall (1956) and Schindler (1956) independently formulated herbaceous cover sprays with endrin as the rodenticide. The procedures as devised in Virginia were highly effective over the wide range from relatively few to many forbs in the cover. Unfortunately even at the start only a slim margin of the necessary forbs occurred in a few orchards. For these broadleaf deficient areas, any downgrading of forb incidence quite rapidly destroyed the base for the satisfactory employment of endrin. In some orchards, even from the start of sprayed rodenticidal treatments, failure was associated with the near absence of forbs. With the decline of these broadleaf plants, the consequence was a serious reduction of on-the-surface feeding. In many areas, the management procedures for succulent cover have markedly favored an increase in grass dominance to the detriment of broadleaf herbs. Without any other ulterior factor, toxicant failure seemed to be assured with too much artificially contrived coincidental decrease in forb content in such covers. Against this somewhat dismal picture for certain orchards, growers in many of the more suitable locations report that they find endrin to be fundamental in their operations.

At the start of the present phase of the study, the Environmental Protection Agency (EPA) outlined a program for possible acceptance of CPN in operational practice. This paper delineates a portion of the effort to satisfy the governmental agency. Any critics of the experimental program as here reported must realize that the new CPN is powerful and that, even for experiments, it is strictly supervised by federal agencies. Because of the then ever present possible threat of an invoked requirement to destroy a highly valuable crop of fruit, that was grown on treated land, many of the desired number of replications had to be foregone.

METHODS

By means of gas chromotography analyses with a sensitivity of 25 ppb, determinations were made for the persistence of CPN residues on foliage of sprayed herbaceous cover. Possible toxicant translocation to apple fruits from ground sprayed orchards was similarly evaluated. Runoff water from plots was also analyzed for the presence of the toxicant. The toxicity of two oxidation products of CPN was determined. Oral LD_{50} values were measured. Another facet involved was a study of types of trailing and their bearing on feed storage and related ingestion of toxicants. Both selected grasses and forage forbs are shown as crucial to the full population management program.

The initial study of herbaceous cover and its relation to pine mice was to map the two observed types of on-the-surface trail systems. Figures 1 and 2 show the runways as found within the two furthermost extremes of herbaceous cover types that are likely to be seen in a grassland orchard. These are either mostly a single species of grass or the desired antithetical, rich and varied forb-grass combinations. The forb-grass pattern is associated with a probable high degree of success with correctly applied herbaceous cover sprays.

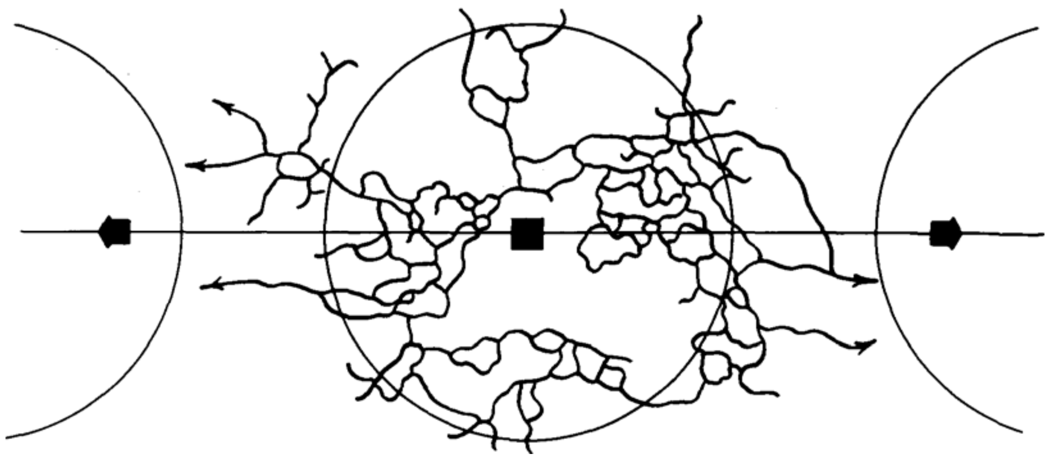

Figure 1. Desirable on-the-surface pine mouse trail pattern for extensive above ground feeding *on* forbs and surface growing rhizomes. High probability of success with herbaceous cover sprays.

Plots and Plot Selection

Only moderate to heavily infested pine mouse orchards were selected for treatment evaluation plots. Mostly the suitable plots were found in well drained topography such as ridge tops. Six row plots of apple trees with the fewest vacant spaces in the two center rows were chosen. In the present cases, the plot was as long as seemed necessary to insure the desired number of 14 sites of mouse activity. See Figure 3. The thickness and density of selected herbaceous cover was moderate so as to represent an average orchard. A minimum requirement for a candidate plot was that it should exhibit at least a modicum of on-the-surface pine mouse activity which is associated with the trailing type as mapped in Figure 1. Herb sprays can only be expected to give control where it is possible to apply toxicant to the feed of the animal. Subterranean mouse feeds cannot be sprayed. The presence of forbs in adequate numbers together with the interjoining type of trails are the best indexes of control potential with ground sprays.

Within each plot, attention was maintained only *to* the center pair of the six rows. As a screen to prevent movement of outside mice into the plot center during the cool season, two standard spaced apple trees and two similarly spaced rows of trees were employed to give a guard strip about 60' to 70' wide. All plot center contacts were made with the mouse colonies at sites located in the tunnel system which is about 2-1/2 inches below the soil surface.

Each location of suspected pine mouse presence was supplied with a firm ripe apple, preferably of the two inch size. Before placement of the apple, a single thin one inch diameter segment of peel was removed from the cheek of the fruit. The cut-face of this apple was placed either on top or alongside the lumen of a shallow tunnel. This exposed fruit pulp closely simulates the type of feeding station that is regularly self-established by the mouse. Each tree in both of the chosen center lines of trees were similarly examined for possible activity. Some trees may exhibit no suitable presence of the animal. For the purpose of this three-state study 14 activity sites in shallow tunnels were regularly chosen for each plot that was replicated three times. To insure the observer's access to the tunnel locations under the later hard freeze conditions, it was essential to cover each site with a 12 x 12 inch square of lumber. Large pieces of edging from lumber mill waste are excellent and were employed.

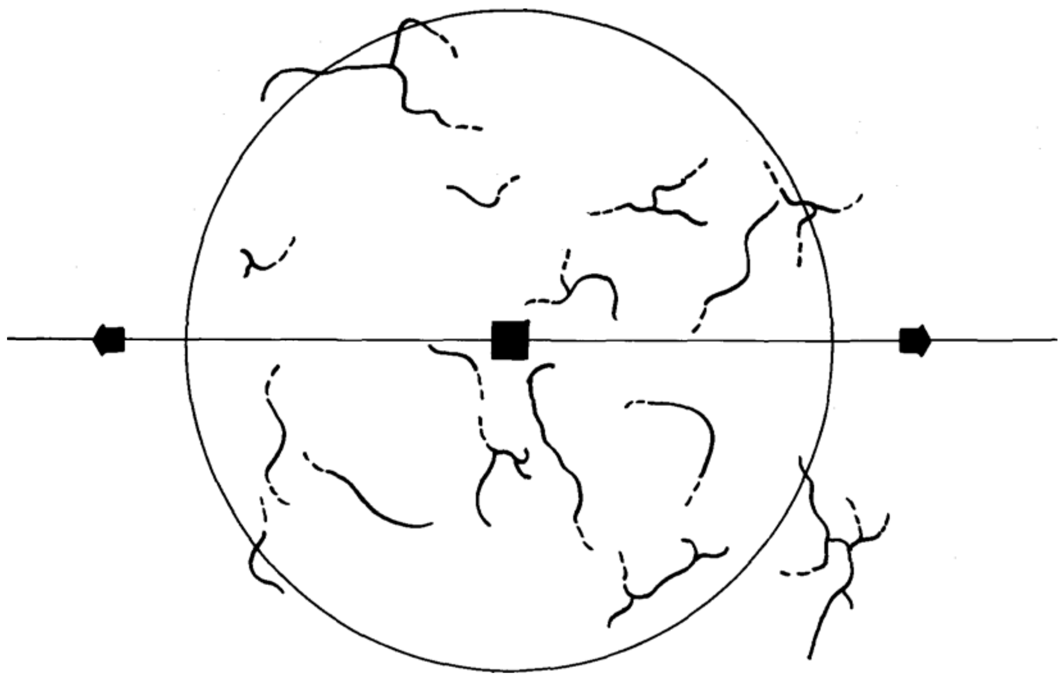

Figure 2. Undesirable on-the-surface trail pattern for a one species cover of the rhizomatous quack grass. Near total underground feeding. Runways chiefly connect the shallow tunnel system to dumps for the excavated soil that has resulted from mining of subterranean rhizomes. Dashed lines represent tunnel entrances. Failure of herbaceous cover sprays almost certain.

Upon examination after about 18 hours, including one overnight exposure, all sites with somewhat more than a nibble of apple were temporarily retained. A maximum of the two best suitably spaced activity stations under any of the chosen trees were eventually selected. All of the other tentative locations were discarded. Preferably these choice positions should be in opposite quadrants. Sites were 10 feet apart unless on opposite sides of the tree. Many trees provided only one station. Intensity of activity at any given cut-apple station is indicated by the quantity of pulp consumption. The more fruit feeding the more desirable is the locale for use as a later measure of post-toxicant effect. No doubt exists that we are dealing with pine mice as their tunnels, mode of life and work in general are as distinctive as many taxonomic features. Moreover according to Horsfall (1964), any acceptably strong pine mouse colony carefully guards its tunnel system against intruders, so that nearly any feeding from tunnels can reliably be assigned to pine mice.

<u>Toxicant Applications</u>

About 95% of all on-the-surface feeding trails and the resultant strip to be sprayed was regularly restricted to the continuous tree-line band as wide as the limb-spread. Therefore, only a maximum of approximately 2/3 of the total cover of the orchard was sprayed. Experience has shown that, for the desired thorough coverage of vegetation in most orchards, close to 10 gallons of spray solution were required per standard seedling rooted apple tree of mature size. With 40 such full size trees per acre, 400 gallons of spray were needed. Because of the trail pattern, it is obvious that the volume per tree is related to tree size and the number of trees per acre. The coverage per acre for any rate of treatment is a variable that is mainly dependent on limb-spread and the number of tree lines. The same number of smaller trees with half of the limb spread of the mature plants would require a maximum of only 50% of the recommended gallonage per tree to give the same desired coverage. The machine traveled alleys constitute about 1/3 of the orchard floor but contain roughly 5% of the surface trails. These latter runs are most likely to be intertree connections and across the alley were not sprayed.

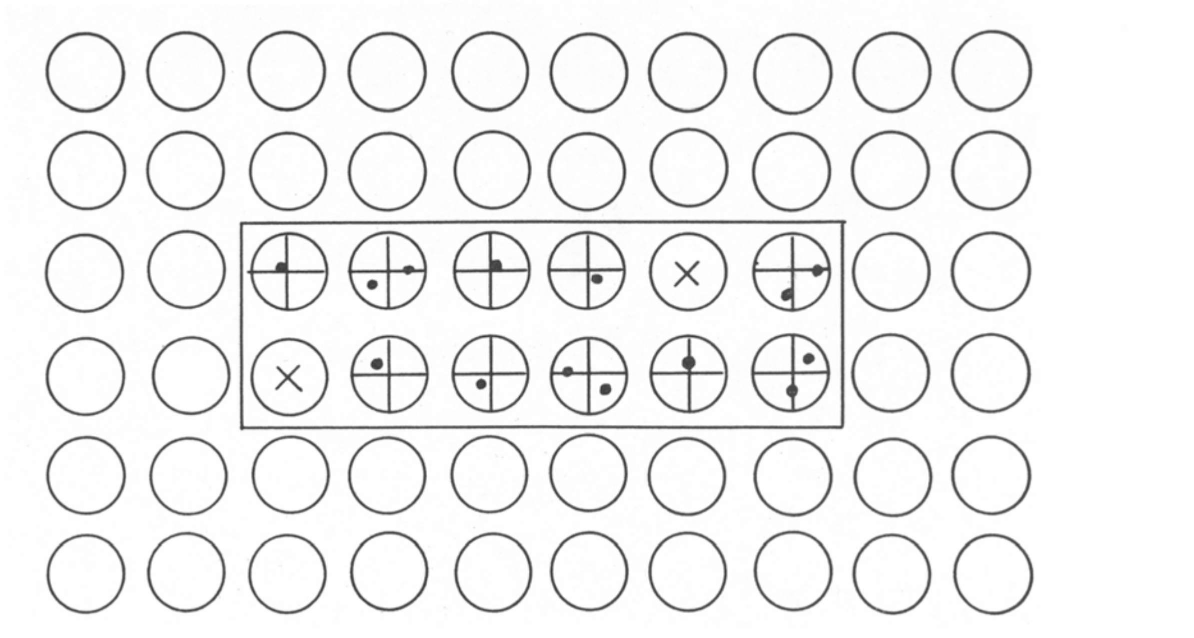

Figure 3. A representative map of 60 apple trees for an experimental plot as employed to evaluate the effectiveness of herbaceous cover sprays. The surrounding outer two lines of trees constitute a peripheral guard strip to prevent the cool season incursion of non-resident mice. Any given treatment was applied to the whole plot. Activity determinations were based on that found in the center block of 12 trees. Dots represent active sites in the shallow tunnel system.

In the present experiments, the toxicant was applied to the ground cover as a spray by a snap-on and snap-off trigger type of hand spray gun as manufactured by the Bean Spray Machinery Company. Previous to the start of operations, the per minute output of the gun was determined at the 500 lbs. per square inch pressure used. The spray time for each tree was measured with a stop watch. The disc orifice was 7/64 inch in diameter. In spraying, the gun was adjusted so that the spray cone was approximately three inches in diameter at the point of impact with the green ground cover. The location of cover contact, ideally about seven feet from the operators position, might at times of near necessity be increased to 10 feet. The angle of spray incidence in reference to the ground varied between 12° and 17°. The gun was moved back and forth in a manner to give side to side sweeps of the nozzle. The horizontal distance between parallel sprayed lines on the ground was close to 15 inches under most cover situations.

The object of the devised spray technique was to make certain that the ricochet effect of the spray from the ground was such as to thoroughly wet all plant surfaces to the full depth of the above ground tree-line feed of the mouse. As in all hand spraying, a bit of a judgment factor intrudes as to what satisfies the needful objective of thorough coverage. For operator safety, the spray gun was pointed at right angle to the direction of wind movement. The uniformly wide limb-end to limb-end treated strip extended the entire length of the tree-line. As the wind direction could readily change, the parallel lines of spray coverage might make any angle with the tree-line. For attachment to the rear of a spray machine, we have fashioned a seven foot high so-called vertical boom with seven suitably placed guns, so directed as to make spray contact with the cover at correctly spaced intervals. As many of these guns are working at any one time as is required to give the proper strip width to one side of the tree. However, in all present experiments the single hand gun was employed.

Measurement of Treatment Effect

The percentage-wise evaluation of post-treatment activity was based on the number of originally active sites that continued to show feeding on the freshly exposed apple pulp. For example, in the post-treatment period any two sites with nibbled apples out of a plot total of 14 stations would be valued at a rounded number of 14% for the residual activity rating. For post-treatment evidence, the presence of any marks by mouse teeth was recorded as activity. Beyond this, the federal agencies emphasized trapping as the ultimate measure of treatment effect.

As trapping terminates an experiment, the problem arises as to when to determine post-treatment effect. Some measure for monitoring the usual slow population decline, after ground sprays, was required. The disappearance of the toxicant residue in about 30 days was one indication of when to trap. Whether, before 30 post-treatment days, the animals would sustain enough physiological damage to die after the first month was not and has not been fully determined. Trapping too soon would be ruinous--beyond some optimal period any such kill might similarly jeopardize the experiment. While the full lethal effect might not be present at the time selected, it was decided to terminate the trials when mouse presence wanted to a point indicated by a 25% or less of residual pine mouse activity. Maturity and sex of all such captures were recorded. The 25% level would represent a persistence of two or three mice from an original per acre number of 25 to perhaps 40 or more. The final results were determined by snap trapping.

RESULTS

Evaluation of CPN Control

The Table 1 data from three states demonstrates further the successful verification of three earlier Virginia trials with CPN. The principal forbs that seem to stand in causal relation to control in the three states mentioned in Table 1 are listed in Table 2. As opposed to New York and Ohio, West Virginia is near the center of the geographical range and is an area of high pine mouse hazard. Geographically, the other two states lie along the outer limits of greatest potential for mouse injury. Both in New York and in Ohio, plots were difficult to locate but in no sense were those selected in any way marginal to the requirements for control evaluation. Statistical analysis of the data from all three states showed very high significance. Tables 3 and 4 and much other experience indicates that six to eight species of forbs is entirely enough if each is well distributed and adequately represented. The confidence limits for the three-state study is 95.5 percent.

The variable survival rates from zero to five individuals in the different CPN treated plots are listed in Table 1. The winter time capture of a juvenile in the Ohio Plot 2 is a partial substantiation of the findings of Horsfall (1963) and Rhodes (1903) that pine mice may breed all of the year. Because of the trapping of the juvenile, it is postulated that one or more breeding individuals among the four adults that were taken in Ohio Plot 2 had invaded at some time in the warmer than usual post-treatment period. Nowhere else in the total study with CPN has an immature subject been seen in the sprayed plots after a suitable post-treatment period. As all or nearly all pine mice die under the applied CPN controls, it is most difficult to see how reproduction of resident mice could occur.

A reference to the right hand columns of Table 1 will give some indication that on the average each persisting mouse can be expected to account for around 7% to 10% of the terminal activity values. These percentage values are only applicable at the low terminal activity levels and obviously not for any greatly enlarged ratings for mouse presence. On the basis of such figures, it has been concluded that an ending activity status near 25% implies an efficient control. This acceptance of close to 75% of post-treatment decline in activity is based on the idea that a properly constituted orchard cover has the necessary mouse carrying capacity to permit trees to satisfactorily withstand such a slight post-treatment infestation and function in an excellent manner.

Table 1. Pine mouse control with chlorophacinone (CPN) ground cover spray. Toxicant rate 0.2 lbs/acre. Treatment periods--October 1971 to first of January 1972. It is significant that no juveniles were taken in any toxicant plot except one in Ohio. It had been postulated that none such would be trapped. The capture of a single juvenile is likely proof of an invasion in a mild winter to give a total of 5 individuals.

State	Post-Treatment Period (days)	Plot	Sex of Survivors Male	Female	Juveniles	Total Survivors	Terminal Activity %
West Virginia	58	No CPN	12	7	8	28	100
		1	0	1	0	1	7
		2	0	0	0	0	0
		3	1	0	0	1	7
		4	2	1	0	3	21
Ohio	69	No CPN	9	6	5	20	79
		1	0	1	0	1	14
		2	1	3	1	5	36
		3	1	0	0	1	7
New York	34	No CPN	1	6	1	10*	86
		1	1	1	0	2	29
		2	0	1	0	1	21

*To equal the 4 terminally active stations in Plot 1 only 4 of the 12 active stations in the no CPN plot were trapped.

Table 3 illustrates the role of forbs as carriers of CPN to improve the performance of herbaceous cover sprays. The reduction of forb content between Orchards 1, 2 and 3 appear to be clearly related to the decline from perfect kill of pine mice to practically complete failure of control. A near total early containment of pine mice would have been expected in Orchard No. 2 if only more adequate numbers of the few species of forbs had been present. The first mentioned 50% status, as exhibited by Orchard No. 2 of Table 3 was not an adequate control except possibly under the seldom seen high dominance of forbs. It seems probable that a moderate increase in the occurrence of forbs in each species at hand would have produced an early decline to the desired control level of 25% or less. The final reduction to 8% after 52 days in the second orchard supports the long time conclusion that numerous forb species are not essential for lethal action. However, enough individual broadleaf plants in each species are a near minimal requirement. Without some adequate profusion of forbs, the ingestion of the spray toxicant is slowed toward control failure. Because of the frequent turf density and the presence of underground rhizomes, grasses alone do not induce a sufficient toxicant intake. As mentioned, even selected grasses seem to have but a small role in toxicant ingestion. These choice grasses function chiefly as tree protectant feed alternates during all seasons.

The Environmental Effects of CPN

To measure CPN residue persistence in mouse control plots, analyses were made for two rates of application on the foliage of forbs with one test being made on orchard grass. Even with the variable residues that remained after nine days, none could be detected 31 days after treatment (see Table 4).

In 1970 to evaluate the possibility of CPN translocation to apple fruits, two pounds of toxicant per acre, which is 10X the control rate, was applied in the recommended pattern to the herbaceous cover along the tree lines of York and Red Delicious. No detectable CPN occurred either in the first crop that was harvested 3-1/2 months later nor in the two succeeding crop years. Test sensitivity was 25 ppb. Similarly in other 1970 trials and in subsequent studies in three other states, a mouse control rate of 0.2 pounds of CPN per acre produced no detectable residue in apple fruits. Under the conditions, these analyses quite strongly indicate no translocation of CPN.

Table 2. The significant herbaceous species that were associated with the successful use of CPN in each of the 3 states. Grasses were everywhere dominant but were plentifully interspersed with forbs.

Common Name	Botanical Name	Species As Found In: Ohio	N.Y.	West Va.
Forbs				
Dandelion	*Taraxacum officionale*	√	√	√
Broadleaf plantain	*Plantago major*	√	√	√
White clover	*Trifolium repens*	√	√	√
Narrow leaf dock	*Rumex crispus*	√	√	√
Yellow wood sorrel	*Oxalis* spp.	√	√	√
Horse nettle	*Solanum carolinense*	√	√	√
Broadleaf dock	*Rumex obtusifolius*	√	√	√
Narrow leaf plantain	*Plantago lanceolata*	√	√	-
Wild carrot	*Daucus carota*	√	√	-
Sheep sorrel	*Rumex acetosella*	√	√	-
Yarrow	*Achillea millifolium*	√	√	-
Hedge bindweed	*Convolvulus sepium*	√	-	√
Number of significant forb species		12	11	8
Grasses				
Orchard grass	*Dactylis glomerata*	√	-	√
Timothy	*Phleum pratense*	√	√	-
Blue grass	*Poa pratensis*	√	√	-

Table 3. The variable occurrence of forbs as associated with the lethal effect of CPN ground sprays. After 52 days the activity in the second CPN treated orchard declined to a final 8% to suggest that the sparseness of forbs in Orchard No. 2 indicates a probable breakpoint between success and failure.

		Orchard No. 1 Forbs Dominant (Grasses adequate)	Orchard No. 2 Forbs Deficient (Grasses dominant)	Orchard No. 3 Only Traces of Forbs (Grasses highly dominant)
		CPN 0.1 lb/acre	CPN 0.2 lb/acre	CPN 0.1 lb/acre
Activity persisting 33-37 days after CPN treatment		zero	50%	90%
Toxicant employed in the check		Endrin 2.0 lbs/A.	Zn_3P_2*	No toxicant
Terminal activity in the check		33%	68%	100%
Forb Species Present	Botanical Name			
Dandelion	*Taraxacum officionale*	√	√	√

Table 3. Continued.

Forb Species Present	Botanical Name	Orchard No. 1 Forbs Dominant (Grasses adequate) CPN 0.1 lb/acre	Orchard No. 2 Forbs Deficient (Grasses dominant) CPN 0.2 lb/acre	Orchard No. 3 Only Traces of Forbs (Grasses highly dominant) CPN 0.1 lb/acre
White clover	*Trifolium repens*	√	-	√
Narrow leaf plantain	*Plantago lanceolata*	√	-	√
Broadleaf plantain	*Plantago major*	√	-	√
Wood sorrel	*Oxalis* sp.	√	-	-
Yarrow	*Achillea millifolium*	√	-	-
Cinquefoil	*Potentilla* sp	√	-	-
Honeysuckle	*Lonicera japonica*	√	-	-
Upland cress	*Barbarea verna*	√	-	-
Wild strawberry	*Fragaria virginianum*	√	-	-
Broadleaf dock	*Rumex obtusifolius*	√	√	√
Aster	*Aster* sp	-	√	-
Wild onion	*Allium cernuum*	-	√	-
Number of Significant Forb Species		11	4	5
Grass Species Present	**Botanical Name**			
Blue grass	*Poa pratensis*	√	√	√
"Muley" grass	*Muhlenbergia* sp	√	√	-
Sedge	*Cyperus* sp	√	-	-
Orchard grass	*Dactylis glomerata*	-	√	√
Quack grass	*Agropyron repens*	-	-	√
Number of Significant Species of Grasses		3	3	3

*Zinc Phosphide (2% toxicant in 8 lbs. of grain/acre)

Thirty-six adult to near adult opossums, trapped in the wildlands, were employed in a randomized test for CPN toxicity to a non-target species. A male and a female were paired in each of six cages of 110 square feet each. In all cages the cover was composed of both forbs and grasses as they occur in a desired typical herb complex. Five of these cages received the standard 0.2 lb. of CPN per acre rate of spray. The sixth cage received none of the toxicant. This six cage trial was replicated three times. No visible lethal action from the toxicant was observed among any of the animals. A thorough post-mortem examination produced no evidence that the health of the animals was adversely affected. In regard to

CPN on non-target species, it is most pertinent that birds are reported to have a quite high LD_{50} value.

Table 4. Persistence of chlorophacinone (CPN) on green foliage (test sensitivity 25 ppb).

Herbs Sprayed	CPN Per Acre	Residue on Foliage (ppb) After 9 Days	Residue on Foliage (ppb) After 31 Days
Forbs	0.10	170	0
Forbs	0.20	228	0
Orchard grass	0.20	776	0

Similarly, a rapid decline of toxicant residues in the soil is most favorable to any proposed schedule for herbaceous cover sprays. Table 5 depicts the elimination of CPN residues at the soil surface to values below that of the test sensitivity. This decrease occurred within 42 days of the post-treatment period. Soon negative readings were obtained at all levels to a depth of 36 inches. Similarly, in a set of three times replicated plots no CPN could be detected in runoff water from the treated areas.

Table 5. Chlorophacinone residue persistence in Lodi Silt Loam as a result of spraying herbaceous cover. Toxicant rate 0.2 lbs. diluted in 375 gallons per acre (test sensitivity 25 ppb).

	Date of Soil Analysed Residue in ppb				
Soil Depth	4/20/71	5/9/71	6/1/71	7/12/71	9/15/71
1/2 inch	113	460	20	---	
1 inch	40	43	20	---	negative
3 inches	---	---	---	negative	---
7 inches	---	---	---	negative	negative
12 inches	---	---	---	negative	---
18 inches	---	---	---	310	negative
24 inches	---	---	---	---	negative
36 inches	---	---	---	---	negative

The toxicity of possible degradation products of new toxicants is a major concern. Oxidation products were considered to be of more likely occurrence in nature than those that result from reductive degradation. At a level of 800 mg/kg in corn oil, 4 chlorobenzophenenone oxidant of CPN produced no mortality during a seven-day observation of five treated pine mice. Likewise under the same conditions no lethal effect was found with another oxidation product, phthalic acid, at 250 mb/kg.

DISCUSSION

Endrin Spray Failures

The foregoing described relations between the lack of several forb species along with a deficiency in actual numbers of such plants has been associated with endrin spray failures over a period of 20 years. Even a 60% increase in the recommended 2.0 lbs. of endrin per acre did not produce pine mouse control when forbs were too few as in CPN treated Orchard No. 3 of Table 3. On the other hand experimental plots in many years have not failed when four to five or more species of forbs were each in sufficient numbers. As a requisite in plot selection, where success was the objective, Figure 1 type of on-the-surface trailing was always sought.

Endrin Resistance in Pine Mice

Webb and Horsfall (1967) measured an individual increase of acquired tolerance and also a genetically based resistance of 10 to 12 fold in populations as exposed to annual endrin treatments in orchards. These Increased physiological capacities to endure the lethal action were quite moderate when compared to specific insect resistance to certain other materials. Even the lesser exhibited powers of pine mice beyond that of non-exposed populations strongly emphasize the need for the maintenance of forb toxicant carriers at appropriate levels.

In the absence of continuing endrin applications, the LD_{50} value for the resistant strain moved downward from a high of 32 to 42 mg/kg to 19 to 21 mg/kg. Sex related endrin resistance differentials, if any, were small. For endrin susceptible strains of pine mice, the LD_{50} value, which can be a little larger for some such populations, may be accepted as about 3.0 mg/kg. See Table 6, where it will be noted that the endrin resistant females were slightly more vulnerable to CPN than the endrin susceptible strain. Although the small difference is not of practical value, the data in Table 1 at least show that endrin resistance does not impede the lethal action of CPN. Accordingly in orchard practice, the sometimes difficult endrin resistant strains apparently could be readily eliminated by CPN applications. In the event that CPN resistance ever became evident, occasionally alternating endrin with CPN apparently should continue to maintain herbaceous cover sprays as dependable controls. Beyond some relatively low degree, toxicant tolerance for a lone ground cover rodenticide would well be ruinous.

Table 6. Comparison of LD_{50} values (mg/kg) of chlorophacinone for endrin susceptible and resistant strains of pine mice. Confidence limits 95 percent. LD_{50} values in ppm in the diet.

Sex	Administered	Strains--Reference to Endrin Resistance	
		Susceptible	Resistant
Female	Oral	3.6	1.1
		(2.2-4.9)	(0.1-2.0)
Male and Female	In Diet	2.1	
(pooled)		(1.6-2.5)	

The Value of Activity Measurements

Contrary to detractors, the activity status determinations constitute a most excellent procedure for measurement of treatment effect. The rate of hazard decline can be measured as needed--a "time perspective" of the effect of toxicant action is obtained. Comparative plots, will in the end, show the minimum toxicant application necessary to reach the desired effect. Knowledge of this latter minimum enables the employment of slow acting herb cover sprays to the best effect. In contrast to the activity method, trapping is costly, laborious, and excessively demanding of research time. One of the authors in working alone once maintained 65 simultaneous toxicant screening plots of 1.2 acres each. The screening problem would have been so slow as to be near hopeless by any method of conventional trapping.

The Need for Near 100 Percent Kill

Brody and associates (1934) have concluded that the basal metabolism of animals, and therefore their requirements for nutrients, is proportional to the 0.73 power of the live weight. The relevant data when plotted for a wide range of body sizes gives a logarithmic curve that approaches the vertical for diminutive mammals the size of pine mice. It will be observed that these rodents not only attack critical areas of the tree but, as shown, have a towering net energy need per unit weight. The consequences are an enormously destructive potential for even a few subjects. The foregoing and much else, as detailed in this paper, account for the time-honored failure of baits to control pine mice. In practice and in research the continuing objective must be to attain 100% kill or nearly so, which rodenticidal sprays can and do achieve.

Several reasons exist for the usual less than 100% kill from the employment of 0.2 lb. of CPN per acre. Permissible ceilings for residue and the need for cost economy for such a toxicant force the employment of the least effective rate of application. Unacceptably high rates of the lethal agent would almost certainly guarantee total elimination of the subjects. For the minimal applications, it will be obvious that the few more resistant members of the population will fall heir to all of the pre-spray subterranean caches as stored by the originally larger numbers. Moreover, these caches will be toxicant free and therefore furnish a massive shield of feed to dilute or totally exclude effective lethal action.

The Twin Roles of Herbaceous Vegetation

It has long been known that herbaceous plants play an important role in tree protection against pine mice. Silver (1924) reported that mouse attack was less where herbs are at hand. The foregoing statement was made 28 years prior to the initial evolvement of the second role of ground herbage--that of induced ingestion of toxicant. Silver in writing of the value of herbs further sets forth that where a long growing season for herbs was present, such herbage appeared to provide a lengthened tree protective influence. Obviously nothing can be done in any given orchard to lengthen the growing season of indigenous vegetation. In comparison with an extended growing season, the artificial seeding of perennial forbs and selected grasses with highly attractive winter persisting foliage, crowns, and rhizomes even more greatly improves the desirable protective requirement than would a long growing season. The presence of these highly acceptable perennial or biennial forage sources of varied types simulates the nutritional effect of a long growing season and essentially resembles an active vegetative period that lasts throughout the year.

As far as the literature on pine mouse shows, Silver's findings have been almost totally neglected. The inherent and probably essential preference of mammal herbivores for feed variety is thoroughly established according to Stoddart and Smith (1955). For mice, such a choice for a mixture of plant species has received scant if any attention. Along this line it must never be inferred that herbs alone are a complete answer. Toxicants are unalterably an essential second but not lesser half of the management schedule.

In many orchards the mouse diet is restricted more or less to two plant species--one the tree and the other a grass. Under these forb deficiency conditions and regardless of mouse numbers, the animals are considered to be forced by the broadleaf requirement to a heavy dependence on trees. With a ratio of succulent forage of five to six or more forb and grass species in variety to one species of tree, provision is at once made for feed diversity. An enlargement of the nutritional base is thereby made available. Marked tree protection ensues because the tree becomes one of a number of forages in the feed base instead of the highly dangerous one tree to one herb species ratio. Unfortunately many of the past cover management procedures in the orchard have favored the dominance of grasses. Even plentiful numbers of rock outcrops have favored mouse control because these prevented the operational elimination of forbs. By the procedures of close mowing and other cultural practices, many forbs have been seriously suppressed.

The Meaning of Surface Trail Patterns

As before stated, the two above ground trail patterns are shown in Figures 1 and 2. Both kinds of runways are used for the disposal of excavated soil, but a principal role of Figure 1 runs is to provide access to above ground feeding on forbs. Figure 2 trails in a near total quack grass cover are not used significantly for feed but almost solely for access to dumps for excavated soil. It will be noted that these Figure 2 above ground trails are short and do not inter join with other runways to form an intricate maze of avenues. Under almost all 100% grass covers, where forbs are absent or nearly so, little or no reason exists to construct the more hazardous surface passages to feeds that are already provided underground. With predominantly grass covers, surface trails are at a minimum. In consequence, sprays on such covers are almost certain to fail. To provide a tempting feed attractant on the surface to insure toxicant ingestion is a most essential role of succulent covers.

Tunnels and Their Function

In addition to the surface trailways as shown in Figures 1 and 2, subterranean tunnels are found to exist--those about 2 to 2-1/2 inches beneath the sod surface along with a shorter underground system more than 12 inches deep. The latter type ranges downward mostly from 24 to 42 inches below the surface. Fibrous root growths from all types of plants thickly protrude into the lumens of shallow tunnels. These tunnel exposed rootlets and root tips constitute a plentiful source of feed to which toxicants cannot be applied. Spray penetration of shallow tunnels is attractive to some farm advisors and has continued to be recommended by them. It is entirely ruinous of control to attempt even shallow soil penetration of any spray. The above ground herbaceous covers should be sprayed by using only enough drive to thoroughly treat all of the herb greenery without any appreciable piercing of the soil surface.

The before mentioned deep tunnel system provides a heat conserving retreat from low temperatures and as ice-free storage sites for cached feed. The previously cited high net-energy requirement of small "warm bloods" precludes the daily expenditure of body heat to melt a frozen mass of feed equal to or greater than the weight of the animal. Under freeze conditions, the daily feed may consist almost entirely of tree roots or deeply placed caches. The need in winter to provide some rhizomatous grass species for tree protective cacheable non-frozen succulent forage is readily apparent. In much of the winter it will be either ice-free caches filled mostly with nutrient rich rhizomes or tree roots as the forage base. Analyses of grass rhizomes by Le Baron and Fertig (1960) points to the high content of total nutrients. It is abundantly clear that grasses with their rhizomes occupy a prime position in any uninterrupted tree damage prevention schedule.

The chance finding of numerous underground caches yielded an important discovery that grass rhizomes particularly those of quack grass (Agropyron repens) and "muley" grass (Muhlenbergia frondosa) and other rhizomatous Muhlenbergias were primary bases for winter feed. Quack grass rhizomes are most excellent mouse feeds but have at least 2 entirely ruinous characteristics for a mouse infested orchard. This latter aggressive plant is much too potentially dominant and it produces subterranean non-sprayable rhizomes. The mouse feeding, as has been shown, is much too concentrated below ground. The detrimental characteristics of quack grass eliminate it for consideration as desirable cover. On the other hand M. frondosa appears to lack the noxious features of quack grass and is without any malefic effects on spray control. M. frondosa has surface and also subterranean rhizomes so shallow as to force the animals to gather them from above ground. Rhizome based on-the-surface feed is seen to be another route of intake for the rodenticides sprayed on ground cover. Caches of rhizomes from this latter grass are seen to meet both the daily and the cacheable requirements of a pine mouse forage. Plentiful underground storages of rhizomes further enable pine mice to simulate some features of hibernation and reduce feed intake by clustering together in dry, well-insulated nests. A marked conservation of net energy results with consequent reduction in tree-hazard.

Seeding Herbaceous Covers

To insure an effective ground cover to meet the twin roles of herbs in the prevalent 40 tree per acre orchard, it is suggested to seed each of a pair of tree-line forage strips (see Figure 4). One strip for a forb mixture and one for muley grass-- M. frondosa. The forb complex would be seeded alone in a continuous 7-foot tree-line strip just inside of the limb ends on each side of every other alley. To be recommended in the seed mixture are dandelion (Taraxacum officionale), narrow leaf plantain (Plantago lanceolata), broadleaf plantain (Plantago major), white clover (Trifoliurn repens) and perhaps chickweed which is a winter annual. These together with natural seeding of other forb species would be likely to provide for the presence of 8 to 10 or more of these species under and about each tree. Seed from all of the named forbs are obtainable from seedsmen or from seed cleaning establishments.

For the alternate alleys not previously seeded, Muhlenbergia frondosa or a comparable species of the genus should be planted in the same pattern as the forbs. Unfortunately to any but the most careful observers, the earliest stages in muley grass seedlings are easily overlooked, which leads to the false assumption of seedling failure. Both the muley and forb seeded strips are designed to maintain the mouse feed continuity for every tree. In order to preserve the forage base, the grass should be seeded only after the forbs have reached near maturity. In an infested orchard, it is a hazardous error to appreciably destroy at the same time the native pine mouse feed alongside more than one of the two alternate alleys.

As all of the control related herbaceous plants listed have small seeds, a careful seed bed preparation and enough subsequent nurture must be supplied to insure successful germination and livability for the largest possible number of seedlings. Sparse seedling survival, as in nature, is not enough. Unfortunately, growers have a mind-set that enables them quite mistakenly to assume that native plants are tough and need no protection. Merely scattering seeds, as some do, seriously imperils the effort and practically guarantees seedling failure.

Erroneous Counselling

Another disturbing situation that prevents herbaceous seeding is the advice of many weed control specialists. Contrary to the concepts herewith presented, some of these "weedster" advisors recommend excessive and perhaps massive tree-line destruction of herbage in order to eliminate competitive plants. Herbicide manufacturers echo such casts of mind. "Competition" from pine mice is utterly neglected. Unfortunately, some of these counsellors have only a limited concept of the complex system inter-relationships between orchard mice, trees, forbs, grasses, rhizomes, caches and the like. In commenting on such as these kinds of over zealous herbicide specialists, Wynn-Edwards (1965) states that biological investigations tend to be confined to discrete components of a system rather than to the complete system itself. This long standing affliction still marches on.

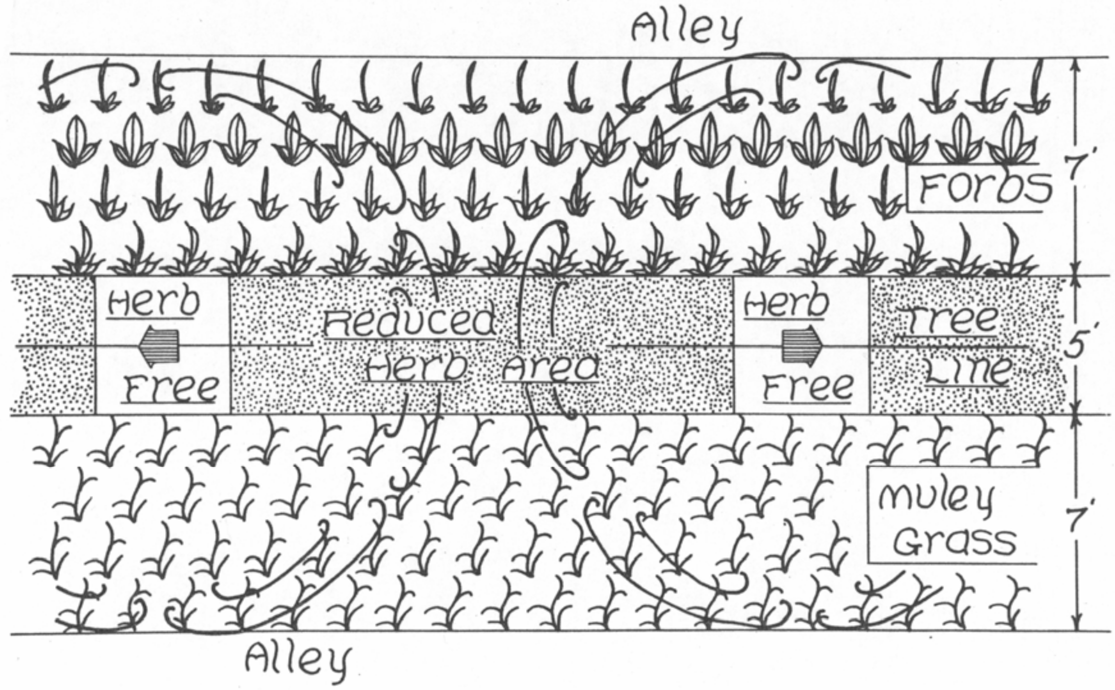

Figure 4. A diagram of the paired forb and muley grass strip as designated for seeding in each tree-line.

Limitation of Population

The true source of population limitation is the central point at issue in any proposed upward modification of mouse feed type or benefit. A major difficulty in grower acceptance of artificial seeding of mouse feed is the deeply ingrained idea that feed quantity directly and more or less quantitatively controls population numbers. In considering the relatively vast mouse feed stocks continuously available in the orchard, it must be obvious that feed is a remote and highly improbable limiting factor in setting the bounds for mouse numbers. McAtee (1936) noted that populations *are* usually checked short of subsistence restriction. Christian (1961) reported that the origins of the self-regulation of populations were multiple and the advocates are many. Kalela (1957) has reported the self-regulation of reproduction in the arctic vole. Kimball (1972) conjectured that factors limiting pine mouse populations are the same as those which governed Chitty's voles (1952).

Practical men labor under the Malthusion fallacy that feed quantity controls the numbers of small herbivorous mammals. The concepts of Mai thus were formulated in the 18th Century by a preacher who principally pondered the problems of human populations and not that of the pine mouse. To circumscribe thought and action by a too rigid adherence to the earliest and more distant demographic concepts leads to serious deficiencies of judgement in regard to lesser mammals.

Summary on the Role of Forbs

Two distinct facets of tree protective influences of forbs are clearly discernible. First, broadleaf herbs attract mice to surface feeding and furnish a principal avenue for the ingestion of toxicant treated forage. Consequently in a range of orchards, a progressive improvement of ground spray control has been closely linked to an adequately increasing incidence of several species of esculent forbs each of which occurs in some profusion. It is a widespread truism for pest animals that any factor, such as forbs, which reduces subterranean living increases the vulnerability of a target species. Secondly, in distinction from many other forms of lower animals, herbivorous mammals are not obligate feeders on a lone species of plant life. Some multiplicity of feed sources by herbivores is eminently preferred and in numerous, if not all, cases essential for the well being of the individual. Apparently the demanding penchant of pine mice for a dietary variety includes most broadleaf forages, including trees, that are available. The only alternative broadleaf feed to that of the tree is the forb group. Where forbs in variety *are* present, the ratio of broadleaf herb species to tree species becomes not one fruit to one grassy herb but four to 10 or more herbs to one woody type plant.

The consequent spread and diverse sharing of the mouse feed base with the broadleaf tree by the many forbs produces the most important protective influences. Not to provide the necessary diversity of broadleaf forage for mice is to force the animals to seriously damage or kill the trees. It can be safely averred that many observers are excessively enamored with the new toxicants. Such potent synthetics may be assigned fallaciously lone roles where assists from nature are definitely in order.

LITERATURE CITED

BLAIR, W. F. 1940. Home ranges and populations of the meadow vole in southern Michigan. Journ. Wildlife Mgt. 4: 149-161.

BRODY, SAMUEL, R. C. PROCTOR and U. S. ASHWORTH. 1934. Growth and development with special references to domestic animals. Mo. Agri. Exp. Sta. Res. Bul. 220.

CHITTY, D. 1952. Mortality among voles Microtus agrestis at Lake Vyrnwy, Montgomeryshire in 1936-1939. Philos. Trans. B236, pp. 505-552.

CHRISTIAN, J. J. 1961. Phenomena associated with population density. Proc. Natl. Acad. Sci. 47 (4): 428-449.

GROLLEAU, G. 1971. Compariasion de la toxicité de divers raticides anticoagulants a l'egard campanol des champs, Microtus arvalis (Pallas). Ann. Zool. Ecol., Anim. 3(2): 261-267.

HORSFALL, FRANK, JR. 1953. Pine mouse control in Virginia orchards. Va. Agri. Exp. Sta. Bul. 465.

_____ . 1956. Pine mouse control with ground sprayed endrin. Proc. Am. Soc. Hort. Sci. 67: 68-74.

. 1963. Observations on fluctuating pregnancy rate of pine mice and mouse feed potential in Virginia orchards. Proc. Am. Soc. Hort. Sci. 83: 276-279.

. 1964. Pine mouse invasion and reinfestation of orchards. Proc. Am. Soc. Hort. Sci.85: 161-171.

_____ . 1972. Chlorophacinone and herbage as potentials for pine mouse damage control. Proc. N. Y. Pine Mouse Symposium pp. 32-46, Kingston, N. Y., January 25, 1972. USDI Bur. Sport Fisheries and Wildlife.

, R. E. WEBB and R. E. BYERS. 1973. How to successfully meet pine mice on their terms.Virginia Fruit 61 (4): 3-15.

KALELA, OLAVI. 1957. Regulation of reproductive rate in subarctic populations of the vole Clethrionomys rufocanus. Am. Acad. Sci. Fenn. Sarja Series A IV Biologica 34.

KIMBALL, GEO. L. III. 1972. Aggressive behavior of the pine mouse. Proc. New York Pine Mouse Symposium pp. 50-56, Kingston, N. Y., January 25, 1972. USDI Bur. Sport Fisheries and Wildlife.

LE BARON, H. M. and S. N. FERTIG. 1960. Relationships between control of quack grass (Agropyron repens) and carbohydrate content of rhizomes. Proc. N. E. Weed Control Conf. 14: 357-362.

McATEE, W. L. 1936. Malthusian principle in nature. Scientific Monthly 42: 444-456.

MOENS, R. and A. GHESQUIERE. 1969. La destruction des rats musques dans les Polders "De Moeren" an moyen d'appats tractés a la chlorophacinone. Revue d l'Agriculture M°8, Aout.

RHODES, S. N. 1903. Mammals of Pennsylvania and New Jersey. 266 p. Philadelphia (Printed by the author)

SCHINDLER, V. 1956. Control of voles with insecticides. Z. Angew. Zool. 1956: 407-423.

SILVER, JAS. 1924. Rodent enemies of fruit and shade trees. Journ. Mamm. 5 (3): 165-173.

STODDART, L. A. and A. D. SMITH. 1955. Range management 2nd Ed. McGraw-Hill, N. Y.

VALENTINE, G. L. and R. L. KIRKPATRICK. 1970. Seasonal changes in reproductive and related organs in the pine vole Microtus pinetorum in Southwestern Virginia. Journ. Mamm. 51 (No. 3): 553-560.

WEBB, R. E. and FRANK HORSFALL, JR. 1967. Endrin resistance in the pine mouse. Science 156 (3783): 1762.

WYNNE-EDWARDS, V. C. 1965. Self-regulating systems in populations of animals. Science 147: 1543-8.
Also discussion 148: 892-3---148: 1669 —149: 1354 and 149: 804.