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Few attempts have been made to quantify the damage to agricultural crops resulting from known densities of a particular pest. Availability of such information, even in its most basic form, is essential to making cost-effective management decisions. The question seems straightforward and simple; however, it is neither. For example, the damage caused by rodents in an apple orchard is not easily observed or measured. Moreover, the ultimate economic effects are dependant to some degree upon tree age, variety and replacement cost; weather, productivity market prices, and a host of other manageable and unmanageable factors facing the grower. In addition to these variables we must admit to not knowing exactly how the degree of girdling damage relates to health and vigor of the tree nor do we understand cumulative or recuperative factors which likely affect a perennial species. We do have evidence that compensatory growth can occur in certain damage situations (see for example Dyer 1973, 1975, 1976; Harris 1974; Hutchinson 1971; Pearson 1965; Vickery 1972; Westlake 1963 and Woronecki et al. 1976). So, while the problem appears clear the answer can be obfuscated by a host of variables many of which can change in a single season.

In an effort to clarify the problem and answer part of this economic question we began a study of the growth and productivity characteristics of known-age McIntosh trees that were subjected to three different levels of pine vole (*Microtus pinetorum*) populations. We anticipate that results from this research will reinforce findings of Pearson (1976) and Pearson and Forshey (1978) who described a reduction in apple crop value due to the presence of voles and subsequent damage to apple trees. Likewise we expect to provide empirical data that can clarify theoretical and speculative estimates of damage such as those of Kennicott 1957; Hamilton 1938; Garlough and Spencer 1944; Biser 1967 and Byers 1974.

## METHODS

Details of the design of this study are presented in a previous paper (Richmond and Miller 1982). Our approach was to 1) build four vole-proof pens around small block plantings of known-age McIntosh trees, 2) stock these pens with pine voles to achieve a high, medium and low density population, 3) maintain these levels by performing tubal ligation to prevent reproduction and replacing adult individuals to compensate for deaths and finally 4) monitor the growth and productivity of the apple trees that were otherwise subjected to a uniform management program.

## RESULTS

Data included in this report are preliminary and are the results obtained from growth and production in 1982 following release of pine voles on 8 November 1981. Twenty-four hours after releasing the individually marked animals, tunnels and burrowing activity was observed in each of the three treatment pens. On 8 December 1981 a brief (6 hour!) trapping effort revealed 13 or the 14 voles indicating that survival was excellent. January and February snow cover exceeded 6 in. at all times in these plots. Periodic checks beneath 18" x 24" tarpaper sheets revealed vole survival in all treated plots. The control plot reamined vole free over this same period. In early March melting snow revealed 5 trees completely girdled and a sixth partially damaged in the high density enclosure; 5 partially girdled in the medium density enclosure and a small area of damage on one tree in the low density pen (Fig. 1). The most extensive girdling extended from just below ground level up to 3 in. above ground. In an unknown situation the nature of the trunk girdling could have been mistaken for damage caused by the closely related meadow vole (*Microtus pennsylvanicus*).

Livetrapping indicated that three males and one female were lost over winter. This loss was presumably due to natural mortality because no indication of predation or even visits by predators was noted.

The effects of three different population densities on the growth and vigor of the trees and on actual fruit production are known for the first year. Although some treatment effects are obvious the data are preliminary and without statistical treatment. Table 1 summarizes the effects on yield and suggests that a negative correlation exists between number of fruits per tree and vole density. The mean fruit weight from the medium and high density pens was somewhat greater however. The reduction in fruit number was not entirely compensated by an increased size (weight) particularly in the high density pen where the total yield averaged about 8 kg less per tree.

The effects of these three vole populations on spur growth and shoot and leaf growth are shown in Tables 2 and 3 respectively. In Table 2 we see no obvious differences in spur leaf number or weight. This would not be surprising after only one year because the spur characteristics for the period that we measured them were already established in the autumn of 1981 before voles were introduced. If spur growth and vigor shows a response it will be observable in the second and subsequent years after vole damage.

Table 1. Effects of pine vole populations on yield and fruit size of 12-year-old 'McIntosh'/M26 apple trees. (Highland, NY-1982)

| | Vole population - No./acre | | | |
|---|---|---|---|---|
| | 0 | 108 | 217 | 435 |
| No. of fruits/tree | 487.6 | 476.4 | 441.4 | 340.3 |
| Yield - kg/tree | | | | |
| Picked | 40.40 | 40.17 | 43.40 | 32.44 |
| Drops | 9.29 | 8.84 | 5.45 | 5.93 |
| Total | 49.69 | 49.01 | 48.75 | 38.37 |
| Pre-harvest fruit drop - % | 18.7 | 18.0 | 11.2 | 15.9 |
| Mean fruit wt. - g | 101.9 | 102.9 | 110.4 | 112.7 |

Table 2. Effects of pine vole populations on spur growth of 12-year-old 'McIntosh'/M26 apple trees. (Highland, NY-1982).

| | Vole population - No./acre | | | |
|---|---|---|---|---|
| | 0 | 108 | 217 | 435 |
| Spur leaves | | | | |
| No. of leaves/spur | 6.3 | 7.3 | 6.9 | 5.8 |
| Weight of leaves/spur - g | 1.00 | 0.94 | 1.05 | 1.09 |
| Mean leaf weight - g | 0.16 | 0.13 | 0.15 | 0.18 |

Table 3. Effects of pine vole populations on shoot and leaf growth of 12-year-old 'McIntosh'/M26 apple trees. (Highland, NY-1982)

| | Vole population - No./acre | | | |
|---|---|---|---|---|
| | 0 | 108 | 217 | 435 |
| Terminal shoots | | | | |
| Mean length - cm | 32.4 | 34.3 | 27.0 | 19.5 |
| Mean weight - g | 2.54 | 2.84 | 2.40 | 1.52 |
| Shoot leaves | | | | |
| No. of leaves/shoot | 16.6 | 14.6 | 16.7 | 12.6 |
| Weight of leaves/shoot - g | 5.86 | 6.26 | 6.34 | 4.54 |
| Mean leaf weight - g | 0.35 | 0.43 | 0.38 | 0.36 |

In Table 3 shoot length and weight appears to decline markedly at the higher vole densities. Likewise the shoot leaves while maintaining similar weights across all treatments do show a reduction in number of leaves per shoot and perhaps in total weight of leaves per shoot.

While the data presented here represent only a single year of effects on one variety at a single life history (productivity) stage (years 10-11) these data provide the type of information that allow some extrapolation to an actual orchard situation. Table 4 projects the loss in gross value on either a 50 ac or 100 ac orchard of similar aged McIntosh trees when apples are averaging $6.50 per bushel. Several additional steps are required to convert these gross values into a figure that reliably indicates loss in net profit. We will not attempt these conversions in this report but plan to do so when all of the experimental results are in hand. Suffice to say that the preliminary indications suggest a substantial negative economic impact of high vole infestations even in a single year of vole damage.

Table 4. Projected loss in yield on 50 and 100 acres (454 trees/A) of 12 year old McIntosh trees. Apples = $6.50 bushel.

| | Projected Loss | | | |
|---|---|---|---|---|
| Vole | 50A | | 100A | |
| Density | bu/A | $ | bu/A | $ |
| Control | -- | -- | -- | -- |
| Low | 900 | 5,850.00 | 1800 | 11,700.00 |
| Medium | 1100 | 7,150.00 | 2200 | 14,300.00 |
| High | 13600 | 88,400.00 | 27200 | 176,800.00 |

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