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William T. Sullivan Jr.

*North Carolina State University, Raleigh, North Carolina*

Turner B. Sutton

*North Carolina State University, Raleigh, North Carolina*

Don W. Hayne

*North Carolina State University, Raleigh, North Carolina*

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## APPLE TREE MORTALITY, RATE AND CAUSES

William T. Sullivan, Jr.  
Turner B. Sutton  
and  
Don W. Hayne  
North Carolina State University  
Raleigh, North Carolina 27650

ABSTRACT: In a randomly selected sample of 47 orchard blocks in Henderson County, North Carolina, over two years, the average annual mortality rate for apple trees was 1.0 percent with probably a little less than half of this caused by voles.

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It is not necessary to tell this group that voles kill apple trees. But to set this fact in context, we are reporting on a study of the rate and the causes of apple tree death based on observations of 28,778 trees for three years and determination of cause of death for 775 trees.

This investigation is part of an interdisciplinary study being carried out by the North Carolina Agricultural Research Service to assemble data for an integrated attack on the management of orchards and orchard pests in North Carolina. This project (acronym:IPOMS) has been described briefly to this group (Hayne 1978).

METHODS: Selection of orchards for this study was effectively at random. A few years before the IPOMS study began, the North Carolina Agricultural Crop Reporting Service had, for another purpose, photographed Henderson County from the air and outlined on aerial maps all of the obvious orchard plantings in Henderson County; for sampling purposes, they designated "blocks" which were orchard areas mostly of two to eight acres. The work areas for the IPOMS study were chosen at random from these blocks. It was not possible to elicit adequate cooperation in 23 of the 64 selected orchard blocks; these were eliminated. The remaining 41 randomly selected blocks represent as close to a random selection as is possible in a practical study. In addition, investigators included eight blocks carried over from other studies; these perhaps were better operated on the average. The IPOMS study is broad-ranging, with the dead tree survey being only a small part. Some results are reported here from 47 orchards; in five of these only partial information was obtained because the method of tree selection, pulling and examination was not acceptable to the grower.

In the blocks covered, the plan was to pull and examine all dead trees during each of the three winters of 1976-77 through 1978-79. Trees were examined in fall before leaf fall, when dead and dying trees could be distinguished easily and marked. Later in the winter they were pulled and the cause of death determined in the opinion of a two-man team made up of the first two authors, one trained in wildlife and experienced in vole control and the other, a plant pathologist working with apples.

Two kinds of information on tree death are presented here, first, estimates of annual mortality rates for this randomly selected sample

of orchards of Henderson County, North Carolina, and second, a percentage allocation of the trees examined to different causes of death based on the judgement of the field crew.

Calculation of mortality rates is complicated by the fact that before we started to identify and remove the dead trees from IPOMS orchards, not all the growers had removed all dead trees every year. Therefore, in some of the orchards (and we did not know which) the dead trees removed the first year were an accumulation of more than one year of mortality and did not provide good information on the annual mortality rate. For this reason, annual mortality rates were determined only from the second and third years' results. We know only to a close approximation the total number of trees living and dead. A count of total living and dead trees was made in February 1976; dead trees were counted in December of 1976, 1977 and 1978. During the following winters the research crew pulled and examined such of these designated trees as the grower would allow. In most but not all cases there was complete agreement as to whether a tree should be pulled; with any disagreement the judgement of the grower prevailed. In a few cases the grower pulled some dead trees as routine orchard maintenance; we believe that in most cases we know the number they pulled. But it may be that the annual mortality rates, calculated from the best information we have, may be slightly underestimated.

The percentage distribution of cause of death is a summary of field records for the 775 trees examined. In judging cause of death the field crew attempted to reach a consensus on the primary cause where two or more factors may have had an influence. Presence of tooth marks on bare wood of roots or trunk, and the edge of the bark being in a distinct line are reliable criteria of vole activity, though not necessarily of responsibility for death.

In distinguishing pine vole damage from that of meadow voles, a number of guidelines were used, and judgement was based on an evaluation of both the damaged tree and the nearby vole habitat in the orchard. Damage to roots and girdling from sod line down is usually associated with pine voles whereas most meadow vole damage is from sod line up. Pine voles seem to begin on the roots and work up. The width of the girdled band is usually greater for meadow voles. Pine vole tooth marks are shorter than those of the meadow vole. Pine voles make more tunnels and holes as compared with more surface runways for meadow voles. Pine voles generally do not leave grass cuttings in the runways but meadow voles will. Pine voles will leave fecal pellets anywhere along the runways while meadow voles generally concentrate them at a few points. Pine vole pellets are smaller than those of the meadow vole pellets.

RESULTS: At the first removal of dead trees from these orchards, 1.6 percent of 28,778 trees were found to be dead and were removed. Individual orchards varied in incidence of dead trees, from 0 to 4.7 percent. During the second and third years of removal when the numbers of dead trees represented annual mortality, on the average 1.0 percent of trees were pulled (1.2 percent the first year, 0.7 percent the second) with this estimate based upon 51,389 tree-years. The highest single value for annual mortality was 5.3 percent; all other values lay

below 3.0 percent.

Table 1. Major causes of death of 775 apple trees in 46 Henderson County, NC orchards; trees pulled and examined during winters of 1976-77 through 1978-79.

Cause of death	Percentage distribution	
Voles		
Pine voles	38.1	
Meadow voles	3.1	
Total, voles		41.2
Disease		
Collar rot	13.9	
White root rot	9.9	
Clitocybe	3.2	
Armillaria	1.8	
Black root rot	0.3	
Root rot (undetermined)	7.5	
Union necrosis (TRSV)	0.3	
Total, disease		36.9
Other identified causes		
Winter injury	1.7	
Top injury	2.8	
Mechanical injury	2.3	
Drowning	4.8	
Roundheaded apple borer	1.0	
Woolly aphid	0.3	
Total, other		12.9
Unknown causes		9.0

Cause of death was determined for a total of 775 trees with allocation to the various identified causes as shown in Table 1. The pine vole was by far the most important single cause of death identified, although the two species of voles together accounted for less than half the mortality. All diseases together were slightly less important than the pine vole.

DISCUSSION: This study suggests that only about 40 percent of these deaths of apple trees in Henderson County were caused by voles. Although this was an important loss, it was exceeded by other causes of death. On the average, the annual mortality rate of trees was about 1 percent, thus the average annual loss to voles was less than 0.5 percent. Higher losses, however, were concentrated in relatively few orchards; we recorded one value of 5.7 percent; we may expect that more extreme values would be found if more orchards were studied.

We recognize that the causes of mortality assigned here were not independent and that the death of any one tree may have resulted from

the combined action of several factors. In particular, an interaction between vole damage and various root diseases seems to be a good possibility and perhaps an important factor of mortality. What role does the vole play in providing a wound through which the tree may become infected with disease? Does the presence of root disease increase or decrease damage by voles?

LITERATURE CITED

- Hayne, D. W. 1978. 1976 IPOMS vole results. pp. 40-48 in Proc. Second Eastern Pine and Meadow Vole Symposium, Beltsville, MD: 110 pp.