Causes of Apple Tree Death in Henderson County, North Carolina

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ABSTRACT

Sutton, T. B., Hayne, D. W., Sullivan, W. T. Jr., Nardacci, J. F., and Klimstra, D. E. 1981. Causes of apple tree death in Henderson County, North Carolina. Plant Disease 65:330-332.

Apple tree mortality in Henderson County, North Carolina, was approximately 1% a year from 1976 to 1979. Vole injury accounted for about half the losses, plant pathogens for about 40%, and insects for less than 2%. Collar rot (*Phytophthora* spp.) and white root rot (*Corticium galactinum*) were the most important root rot diseases.

Apple orchards are generally productive over a 30–50 yr period. During this time, most orchards sustain tree loss from root rots, voles, cold, drowning, etc. Loss in most orchards in North Carolina is estimated to be less than 1% a year, but losses in individual orchards have been substantially greater (3).

Tree death results in considerable loss to a grower: investment costs of bringing the tree to bearing are lost; the tree's annual production is lost; and because cutting off orchard equipment at sites of missing trees is impractical, chemicals are wasted. If replanting is attempted, replant costs must also be considered.

Knowledge of the cause of tree death is important so that appropriate control procedures can be followed if replanting is attempted. For example, if recent vole damage is evident, a rodenticide may be needed; if collar rot killed the tree, certain rootstocks and poorly drained sites should be avoided on replanting.

This survey was undertaken to determine the causes of tree death, their relative importance, and the annual mortality rate in orchards in a pest management program in Henderson County, North Carolina.

Paper 6571 of the Journal Series of the North Carolina Agricultural Research Service, Raleigh.

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0191-2917/81/04033003/$03.00/0

MATERIALS AND METHODS

Orchard and tree selection. Orchards used in this study participated in a pest management program in Henderson County. The 4,124 ha of apple orchards in the county were divided into 1.6 or 3.2 ha blocks on aerial photographs, and 60 blocks were selected for the pest management program by a circular systematic sampling procedure. Owners of 39 of the 60 blocks agreed to participate in the program. Eight blocks that had taken part in another program were also included in this study.

Dead or weak trees were tagged in the fall after harvest but before leaf fall in 1976–1979. Weak trees were identified by purple precoloration of the foliage and reduced terminal growth. Recent replants were not considered in this study.

Trees were pulled during the winter and spring. Sometimes, growers or poor weather prevented pulling of all tagged trees. In two blocks, growers did not permit any trees to be pulled.

Causes of tree death. Tree death was ascribed to 15 causes determined primarily by macroscopic symptoms and signs (1,3–8,11):

- Collar or crown rot (*Phytophthora* spp.) was identified in the orchard by cankers at or just below the soil line and on primary roots. When bark was cut away from the roots, affected tissue was red brown and often water-soaked and moist. A distinct margin separated diseased tissue from healthy tissue.
- White root rot (*Corticium galactinum* (Fr.) Burt = *Syctinostroma galactinum* (Fr.) Donk) was identified by extensive white mycelial growth on the surface of affected roots. Roots were very light in weight, dry, and brittle.
- Armillaria root rot (*Armillaria mellea* Vahl ex Fr. = *Armillariella mellea* (Fr.) Karst.) was identified by a white fungal mat or fan in and under the bark of infected roots and by rhizomorphs on the surface of affected roots. Occasionally, basidiocarps of *Armillaria* or remnants of them could be seen at the base of affected trees.
- Clitocybe root rot (*Clitocybe tabescens* (Scop. ex Fr.) Bres. = *C. monadelpha* Morg. = *Armillariella tabescens* (Scop. ex Fr.) Singer) was identified by a white mycelial fan or mat in or beneath the bark and by black extrusions that developed in cracks in the bark. Basidiocarps or remnants of them were occasionally seen at the base of affected trees.
- Black root rot (*Xylaria mali* Fromme or *X. polymorpha* (Pers. ex Fr.) Grev. = *Xylosphaera polymorpha* (Pers. ex Mérat) Dumortier) was determined by black, fingerlike stroma at the base of affected trees and by black mycelial incrustations on the surface of infected roots. Infected roots were brittle and often broke off in the ground.
- Union necrosis (thought to be caused by tomato ringspot virus) was identified by a constriction and necrosis in the woody tissue beneath the bark at the graft union. These trees often broke off at the union when they were pulled.
- Root rot (unidentified). In many instances, roots of dead or weak trees were rotten, but symptoms and/or signs were not characteristic of the root rots described. These rots were most common after vole injury.

• Broad-necked root borer injury (*Prionus laticollis* Drury) was identified by extensive tunneling in the major roots and the trunk beneath the soil line. Usually, larvae were present for identification.

• Woolly apple aphid injury (*Eriosoma lanigerum* (Hausmann)) was identified by galling on the roots and the presence of aphid colonies. Extensively colonized trees were usually weak and stunted but not dead.

• Pine or meadow vole damage (*Microtus pinetorum* (Lecone); *M. pennsylvanicus* (Ord)) was determined by tooth marks on bare wood of the trunk or roots. Damage by the two species was differentiated by the nature of the injury as well as nearby habitat. Meadow vole damage usually occurs from the soil line up; pine vole damage is usually below ground. Pine voles tunnel more extensively below ground than above; surface runways are more common with meadow voles.

• Mechanical injury was defined as an injury that occurred during orchard operations such as mowing or harvesting and that led to tree death. In most such cases, secondary wood rot fungi were involved in ultimate tree death, but we made no attempt to identify them.

• Winter injury was characterized by extensive bark splitting and separation from the cambium. Injury was most common on the south side of the tree from the ground line to the first set of scaffold limbs. Winter injury often was not extensive enough in itself to kill the tree but predisposed the tree to wood rot fungi.

• Top injury was defined as an injury to the scaffold system of the tree that led to tree death. Such injuries usually resulted from limbs splitting off the tree or from poor pruning that predisposed the tree to invasion by wood rot fungi.

• Drowning was identified by root symptoms as well as tree location in the orchard and planting depth. Wood beneath the bark of affected roots was brown and often streaked with gray or gray black. Unlike collar rot, where a distinct line separates diseased and healthy tissues, necrotic areas blended into healthy areas. Roots often smelled sour, and the bark peeled off readily. In many instances, these trees were planted in obviously wet sites or were set too deeply.

• Unknown. Trees in this category could not be clearly associated with any of the 14 other causes of death. Most trees in this category had been dead for more than 1 yr.

Secondary causes of death. In about 10% of the cases, more than one pathogen or other cause of tree death could be distinguished on the roots or trunk. When this happened, tree death was attributed to the cause producing the most extensive damage, and the other cause was listed as a contributing factor.

RESULTS

In 1976, trees were removed from 35 orchards, and no weak trees were found in two orchards; in 1977–1979, the corresponding numbers were 38 and 3, 30 and 9, and 32 and 8, respectively. The numbers of trees removed in 1976–1979 were 322, 283, 147, and 138, respectively.

Based on trees removed, annual mortality rates for these years were 1.33, 1.04, 0.55, and 0.52%. The 1976 rate may overestimate the mortality rate for this season because during 1976, many weak or dead trees were pulled that should have been removed by growers before then but were not.

On the other hand, this survey may underestimate actual grower losses on a yearly basis. Most of the orchards we studied were 10 yr old or older, and trees were propagated on seedling roots. Tree loss is often more serious in younger orchards. For instance, collar rot is often more severe in plantings 4–6 yr old, and losses greater than 40% caused by collar rot have been noted in North Carolina orchards propagated on size-controlling rootstocks. Southern stem rot caused by *Sclerotium rolfsii,* another problem on young trees in North Carolina, was not detected in this survey. Rabbit and vole damage can also be important in young plantings. Moreover, we did not consider loss of replants in established orchards; such losses may be high because trees are often not given proper care.

Table 1 shows the percentage of trees removed each year, attributed to each cause of death. Although isolations were not made for fungal pathogens and fresh vole signs were not always evident, we believe that our data reflect the actual causes of tree death in the orchard. Cold injury at the crown, drowning, and collar rot may sometimes have been confused. Collar rot was recorded as the cause of death only when a distinct line separated diseased and healthy tissue. We may have overlooked rhizomorphs of *Armillaria* and incorrectly attributed death to *Clitocybe.* Pine and meadow vole injury may have been confused. Whenever symptoms and/or signs were not distinctive, however, cause of tree death was listed as unknown.

Voles were the most important cause of tree death each year (Table 1). Diseases (including unidentified root rots) accounted for 40.5, 35.2, 42.2, and 31.7% of the dead trees in 1976–1979, respectively. Collar rot and white root rot were the most important diseases. Abiotic causes (winter injury, mechanical injury, etc.) accounted for 5.5–14% of tree deaths.

Root borer damage was found mainly in two orchards. Overall, the root borer is an incidental pest with several hosts near the orchard. Woolly apple aphids were generally more common than root borers; many trees killed by other causes had some aphid galling on their roots. How much the aphid affected tree growth is difficult to say from the results of this study. We felt that woolly apple aphid injury severely weakened only two trees.

Secondary causes of death were identified on 130 trees during the 4-yr study. Unidentified root rot fungi associated with pine vole injury were the most important secondary cause of death, occurring on 36.9% of the 130 trees. Pine vole damage was present on 27.7% of the trees, and identified root rots were associated with 16.1%. Broad-necked root borers were found in 6.9% of the dead trees.

Mortality factors differed only slightly among apple cultivars. Only Delicious, Golden Delicious, and Rome Beauty trees were pulled in sufficient numbers to permit comparisons. As expected, collar rot was identified less frequently on Rome Beauty than on the other two cultivars (about 4% compared with 15%)—Delicious and Golden Delicious

Table 1. Causes of apple tree death in Henderson County, North Carolina, 1976–1979

	Percentage of trees affected[a]				
Cause of tree death	**1976**	**1977**	**1978**	**1979**	**Mean**
Diseases					
Collar rot	14.6	17.3	7.5	7.3	13.1
White root rot	10.6	6.7	16.3	9.4	10.1
Clitocybe root rot	3.8	2.1	4.8	5.8	3.7
Armillaria root rot	2.8	1.8	0.0	0.7	1.7
Black root rot	0.0	0.7	0.0	0.0	0.2
Union necrosis	0.0	0.3	2.0	2.1	0.7
Root rot (unidentified)	8.7	6.3	11.6	6.5	8.0
Pine vole	37.6	37.1	45.5	50.0	40.6
Meadow vole	6.8	0.7	0.0	0.0	2.7
Broad-necked root borer	0.6	0.3	3.4	3.6	1.5
Woolly apple aphid	0.0	0.7	0.0	0.7	0.3
Abiotic disorders					
Winter injury	1.2	1.0	1.4	0.7	1.1
Top injury	1.5	5.3	1.4	5.8	3.4
Mechanical injury	0.9	4.9	0.7	0.0	2.0
Drowning	7.5	2.8	2.0	2.2	4.3
Unknown	3.4	12.0	3.4	5.1	6.5

[a] Based on 322, 283, 147, and 138 trees pulled in 35, 38, 30, and 32 orchards in 1976, 1977, 1978, and 1979, respectively.

are planted more extensively than Rome Beauty on the more susceptible size-controlling rootstocks in North Carolina. More Rome Beauty trees were drowned than Delicious or Golden Delicious trees (about 18% compared with 2%), perhaps because Rome Beauty is often planted in lower areas of the orchard, which are often poorly drained. Union necrosis was identified only on Delicious trees. Other causes of death occurred in similar proportions on the three cultivars.

Losses from pine voles occurred in the most orchards. During the four survey years, 50–70% of the orchards sustained tree loss attributed to pine voles. In orchards with pine vole injury, mean losses were 0.86, 0.96, 0.60, and 0.76% for 1976–1979, respectively. Losses in the most severely affected orchards ranged from 2.29% in 1978 to 4.18% in 1977.

Collar rot and white root rot were the most widely distributed root rot diseases. Collar rot occurred in 48.6, 39.5, 23.3, and 28.1% of the orchards sampled in 1976–1979, respectively. White root rot was found in 37.1, 26.3, 46.6, and 25.0% of orchards during the same years. Union necrosis was found in one orchard in 1977, two in 1978, and three in 1979.

DISCUSSION

Much tree loss could be avoided with good orchard management practices. Probably half the apple trees killed by voles in North Carolina could be saved with rodent control. Not only do voles kill trees directly, but they also often predispose trees to attack by secondary wood rot fungi. Control can be achieved through management of orchard floor vegetation and applications of rodenticides (10).

An additional 5–10% of tree loss could be prevented with careful site selection and proper orchard maintenance. A good site helps to reduce the likelihood of freeze injury and provides good drainage to avoid drowning. Better tree training and fruit thinning to prevent limb breakage, proper pruning of broken limbs, and care in orchard operations such as mowing also decrease tree loss.

Reducing losses from diseases is more difficult. The potential for collar rot can be lessened by selecting well-drained sites, bedding if necessary, and avoiding the most susceptible rootstocks. *Armillaria* has been controlled by removing as many old roots as possible from the site, allowing the soil to dry, and treating with methyl bromide or carbon disulfide (2,9,12). Fumigation may not be practical in the heavier soils of North Carolina, where soil does not dry readily. Similar problems in controlling *Clitocybe, Corticium,* and *Xylaria* are anticipated.

ACKNOWLEDGMENTS

The technical assistance of L. R. Pope and Jim McKinley is acknowledged. This study was supported in part by CS Project 701-15-56.

LITERATURE CITED

1. Baines, R. C. 1939. Phytophthora trunk canker or collar rot of apple trees. J. Agric. Res. 59:159-184.
2. Bliss, D. E. 1951. The destruction of *Armillaria mellea* in citrus soils. Phytopathology 41:665-683.
3. Clayton, C. N., Julis, A. J., and Sutton, T. B. 1976. Root rot diseases of apple in North Carolina. N.C. Agric. Exp. Stn. Bull. 455. 11 pp.
4. Cooley, J. S., and Davidson, R. W. 1940. A white root rot of apple trees caused by *Corticium galactinum*. Phytopathology 30:139-148.
5. Cooley, J. S., and Groves, A. B. 1950. Root and collar winter injury of apple trees. Phytopathology 40:355-362.
6. Fromme, F. D. 1928. The black root rot disease of apple. Va. Agric. Exp. Stn. Tech. Bull. 34. 52 pp.
7. Groves, A. B. 1946. Weather injuries to fruits and fruit trees. Va. Agric. Exp. Stn. Bull. 390. 39 pp.
8. O'Reilly, H. J. 1963. *Armillaria* root rot of deciduous fruits, nuts and grapevines. Calif. Agric. Exp. Stn. Ext. Serv. Circ. 525. 15 pp.
9. Paulus, A. O., LaRue, J. H., Wilbur, D. W., O'Reilly, H. J., and Darley, E. F. 1962. *Armillaria* root rot fungus controlled with methyl bromide soil fumigation. Calif. Agric. 16:8-9.
10. Rock, G. C., Sorensen, K. A., Kolbe, M. H., Skroch, W. A., Unrath, C. R., Sutton, T. B., Ritchie, D. F., and Hayne, D. W. 1980. Spray information for North Carolina apples, 1980. N.C. Agric. Ext. Serv. Publ. AG 37. 40 pp.
11. Stouffer, R. F., Hickey, K. D., and Welsh, M. F. 1977. Apple union necrosis. Plant Dis. Rep. 61:20-24.
12. Thomas, H. E., and Lawyer, L. O. 1939. The use of carbon bisulphide in the control of Armillaria root rot. (Abstr.) Phytopathology 29:827-828.