The Effects of Pruning on Incidence and Severity of *Zygophiala jamaicensis* and *Gloeodes pomigena* Infections of Apple Fruit

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Use of trade names does not imply endorsement by the North Carolina Agricultural Research Service of the products named nor criticism of similar ones not mentioned.

Paper 10885 of the Journal Series of the North Carolina Agricultural Research Service, Raleigh 27695-7643.

We would like to thank E. M. Brown and L. R. Pope for technical assistance and R. N. Barber, Jerry Laughter, and David Wyatt for allowing us to work in their orchards.

Accepted for publication 11 March 1988 (submitted for electronic processing).

ABSTRACT

Ocamb-Basu, C. M., Sutton, T. B., and Nelson, L. A. 1988. The effects of pruning on incidence and severity of *Zygophiala jamaicensis* and *Gloeodes pomigena* infections of apple fruit. Phytopathology 78:1004-1008.

The effectiveness of apple tree pruning as a management tactic for control of flyspeck (*Zygophiala jamaicensis*) and sooty blotch (*Gloeodes pomigena*) was investigated at four orchards during 1983–1985. The 1983 growing season was hot and dry, rainfall was near normal in 1984 but temperatures were below normal in July and August, and the 1985 growing season was characterized by above normal rainfall and slightly below normal temperatures in July and August. The incidence and severity of sooty blotch were less in pruned trees than unpruned trees in 1984 ($P = 0.10$) and 1985 ($p = 0.01$) when data were averaged across locations and sampling periods. There was no significant difference between the treatments in 1983. Sooty blotch severity at harvest averaged 9% less in the pruned trees than the unpruned ones over all locations during 1984 and 1985 seasons. The effect of pruning on flyspeck incidence and severity was not clear. The incidence and severity of flyspeck were significantly greater ($P = 0.05$) in the pruned treatments in 1984; there was no difference between the treatments in 1983 and 1985.

The fungi, *Zygophiala jamaicensis* Mason (teleomorph: *Schizothyrium pomi* (Mont. & Fr.) v. Arx) and *Gloeodes pomigena* (Schw.) Colby, cause flyspeck and sooty blotch, respectively, of apple (*Malus* × *domestica* Borkh.) and are common on apple fruit in humid growing regions (16). Numerous other plant species, mostly trees and shrubs, are also hosts to these fungi (2,5,9,11–13,18). These pathogens use the waxy cuticle of apple fruit as a carbon source and barely penetrate the epidermal layer (5,10,14); however, infected fruit are downgraded when marketed. In North Carolina, between 5 and 30% of the apple crop is affected by either of these pathogens, causing an annual loss of 3–17% (19,20).

Colby (9), Latham (18), and others (1,25) have observed that sooty blotch or flyspeck often were more severe in unpruned trees than pruned ones and suggested that pruning to promote drying would aid in the control of sooty blotch and flyspeck. We have also observed less sooty blotch and flyspeck in pruned commercial orchards than those poorly pruned. The value of pruning as a management practice for reducing sooty blotch and flyspeck incidence and severity has been based on orchard observations or observations in fungicide trials and has not been demonstrated experimentally. Thus, the objective of this study was to determine the effectiveness of pruning as a disease management strategy for reduction of incidence and severity of sooty blotch and flyspeck.

MATERIALS AND METHODS

Experimental sites. Two abandoned apple orchards (A1 and A2) and two managed, commercial orchards (C1 and C2), located in western North Carolina, were used. One abandoned orchard, A1, was located in Haywood County, the other, A2, and the commercial sites, C1 and C2, were in Henderson County. A2 and C1 were used in 1983, 1984, and 1985. A1 was used only in 1983 and C2 only in 1985. A2 was located on the Mountain Horticultural Crops Research Station, Fletcher.

A1 (cultivar Rome), abandoned for about 10 yr, was situated on a ridge. Average height and width for the unpruned trees were 5.9 and 6.7 m, respectively. A2, abandoned for 6 yr, was situated on a slight slope (about 10 degrees). Trees were the cultivar Golden Delicious and height and width of the unpruned trees averaged 5.5 and 4.5 m. The trees at C1 and C2 were located on flat land and were Golden Delicious and Rome Beauty, respectively. The average unpruned tree height and width in C1 were 5.2 and 4.1 m and 6.5 and 6.0 m in C2, respectively.

Six trees of similar size and shape were selected in a row in each orchard. Three of the six trees were selected randomly and pruned to a modified central leader during April; the three remaining trees were unpruned. Unpruned trees had extremely thick canopies, fruit spurs were dead or weak in the canopy, and very little light was visible through the canopy. Pruned trees were pruned such that there was adequate light throughout the tree for spur development on trunks and scaffold limbs and there were many openings where light could be seen through the tree (23). After pruning, trees were 0.7 to 1.7 m shorter than unpruned trees.

A1 and A2 received no pesticide sprays during the 1983 study. During 1984 and 1985, A2 was sprayed at 7–10-day intervals before petal-fall with fenarimol at 52.54 g a.i./ha for apple scab control and at 2-wk intervals with azinphosmethyl at 1.12 kg a.i./ha for insect control. C1 and C2 orchards were sprayed each year at 7–10-day intervals before petal-fall with dodine at 1.46 kg a.i./ha for apple scab control. Pesticides were applied with an airblast sprayer.

Disease assessment. Twenty-five fruit on each tree were selected arbitrarily to represent various locations of fruit on the tree, numbered, and tagged during the 1983 and 1984 growing seasons. In 1985, 40 fruit were selected arbitrarily per tree.

Disease incidence and severity were determined for each tagged fruit every 3–4 wk throughout the season. In 1983, percent fruit surface area covered by sooty blotch was visually estimated and number of flyspeck colonies were counted. Discrete flyspeck colonies were difficult to distinguish as the disease progressed; consequently in the subsequent 2 yr of the study, the percent fruit surface area colonized by flyspeck was visually estimated.

Environmental monitoring. A hygrothermograph (Belfort Instruments Co., Baltimore, MD) was mounted 2 m above the ground in the center of the canopy of a pruned and unpruned tree during each season at each site. Hygrothermographs were placed in

46- × 51- × 61-cm shelters with slatted sides. A top-weighing rain gauge (Belfort Instruments Co., Baltimore, MD) was placed in a missing tree site in each orchard.

Statistical methods. The experimental design at each site was considered to be a completely random design with trees nested within treatments. Treatments were two pruning levels (no prune vs. pruned) × the sampling dates (four to six per year). There was sampling within trees (25 fruit/tree in 1983 and 1984 and 40 fruit in 1985). An unweighted average of the samples was used in the analysis of variance. A combined analysis of variance for the 3 yr as well as an analysis of variance for each year was performed using data for all sites and sample dates within each year.

Our major goal was to evaluate the effect of pruning averaged over all dates. We also compared treatments on each assessment date. Least significant differences were computed for comparing two treatments within a sampling date at a site.

TABLE 1. Mean temperatures and rainfall for June, July, and August 1983–1985 and 22-yr average at A2

	June		July		August	
Year	Temp (C)	Rain (cm)	Temp (C)	Rain (cm)	Temp (C)	Rain (cm)
1983	19.5	9.19	22.8	4.75	23.2	2.36
1984	20.7	12.09	21.2	16.05	21.5	15.85
1985	20.8	3.96	21.7	16.00	21.0	23.42
Average[a]	21.0	10.67	22.9	11.25	22.5	12.17

[a] 22-yr average.

RESULTS

Environmental conditions. Environmental conditions among the three seasons varied widely. In 1983, rainfall was below normal in June, July, and August (Table 1). The summer was characterized by two very warm periods from 15 to 24 July and 10 to 25 August. Temperatures exceeded 30 C on 42 days at A2. Rainfall and temperature were near normal during June 1984; July and August were slightly wetter and cooler than normal (Table 1). In 1985, following a dry June, July, and August were wet with temperatures slightly below normal (Table 1). Measured rainfall was recorded on 21 and 22 days in July and August, respectively. Temperatures exceeded 30 C only on 1 day at A2 in 1985. Temperature differences were not great among locations; however, rainfall was variable, as is characteristic of the mountainous region of North Carolina during the summer. There were no consistent differences in temperature or relative humidity within canopies of pruned or unpruned trees.

Sooty blotch. In an analysis of variance of the 3 yr combined, the incidence and severity of sooty blotch were less in pruned trees than unpruned ones (Table 2). When the data were examined by year, the effect of pruning was nonsignificant in 1983, but both incidence and severity of sooty blotch were reduced in the pruned treatment in 1984 and 1985 (Table 2). In 1983, there was no difference in the incidence of sooty blotch between treatments at any location ($P = 0.05$, Table 3). The severity of sooty blotch in pruned trees was less ($P = 0.05$) at A1 through the season (Fig. 1). At A2 and C1, there was no difference ($P = 0.05$) in sooty blotch severity between the treatments although disease severity was somewhat greater in the

TABLE 2. Incidence and severity of sooty blotch and flyspeck from 1983–1985

	Fruit affected (%)				Surface covered (%)			
	Sooty blotch		Flyspeck		Sooty Blotch		Flyspeck	
Year	Unpruned	Pruned	Unpruned	Pruned	Unpruned	Pruned	Unpruned	Pruned
1983	93.8[a]	92.3 ns[b]	71.9	68.5 ns	22.1	22.0 ns	...	...
1984	100.0	97.8 **	58.9	68.3 *	28.9	24.4 +	2.3	3.3 *
1985	81.2	73.7 **	60.4	56.3 ns	28.9	21.6 **	5.4	5.3 ns
Overall (1983–1985)	90.3	86.6 **	65.2	64.1 ns	25.9	22.1 **	4.3	4.5 ns

[a] Means of combined data over location and sampling date.
[b] ns = nonsignificant; +, *, and ** = significantly different from the pruned mean at 0.10, 0.05, and 0.01, respectively.

TABLE 3. Incidence of sooty blotch at each site, 1983–1985

	Percent of fruit affected with *Gloeodes pomigena*[a]							
Year and date	A1[b]		A2		C1		C2	
	Unpruned[c]	Pruned	Unpruned	Pruned	Unpruned	Pruned	Unpruned	Pruned
1983								
15 June	0	0	0	0	0	0		
13 July	69	61	82	73	0	0	...	...
28 July	100	98	100	99	64	63	...	...
10 August	100	100	100	100	99	98	...	...
23 August	100	100	100	100	99	100	...	...
12 September	100	100	100	100	100	99	...	...
1984								
25 June	...	...	0	0	0	0		
16 July	...	...	100	100	100	88**[d]	...	...
8 August	...	...	100	100	100	96**	...	...
3 September	...	...	100	100	100	100	...	...
1985								
13 June	...	...	0	0	0	0	0	0
13 July	...	...	89	59**	55	33**	5	3
27 July	...	...	99	100	100	95	38	24**
24 August	...	...	100	100	100	100	88	91
7 September	...	...	100	100	100	100	99	100
5 October	...	...	...	...	...	...	100	100

[a] Average based on 25 fruit per tree in 1983–1984 and 40 fruit in 1985; three replications were used each year.
[b] See text for description of orchards.
[c] Unp = unpruned treatment and Pru = pruned treatment.
[d] ** indicates significant differences between the two treatments on the date of assessment at $P = < 0.01$, as determined in an analysis of variance.

pruned trees. In 1984, sooty blotch developed rapidly from 25 June to 16 July and on 16 July, nearly 100% of the fruit were affected in both treatments (Table 3). At C1, the incidence of sooty blotch was significantly less in the pruned treatment on 16 July and 8 August. Sooty blotch severity was less in the pruned treatment in C1 throughout the season (Fig. 1, $P = 0.01$). There was no significant difference between treatments at A2. In 1985, the incidence of sooty blotch was less in pruned trees on the second (A2 and C1) or third (C2) sample dates; however, as the incidence of the disease increased, there was no difference between the treatments (Table 3). Sooty blotch severity was less ($P = 0.01$) in the pruned treatment at A2 and C1 in 1985 (Fig. 1). Sooty blotch severity was also less at C2; however, the difference was nonsignificant at $P = 0.05$.

Flyspeck. Pruning had no significant effect on the incidence or severity of flyspeck in the analysis of variance of the 3 yr combined (Table 2). This lack of significance may be due to the inconsistent results that were obtained among years and locations. In 1983 the incidence of flyspeck was generally less in the pruned treatment in A1 and A2; however, the difference was significant ($P = 0.05$) only on 13 July at A1 (Table 4). At C1, the incidence of flyspeck was slightly greater in the pruned treatment on 23 August and 12 September; however, these differences were nonsignificant. In 1984, the incidence and severity of flyspeck were increased in the pruned treatment ($P = 0.05$, Table 2). The incidence of flyspeck was greater in the pruned trees when averaged over all sample dates at A2 ($P = 0.05$); at C1 there was no difference between treatments (Table 4). Disease severity was greater in the pruned trees at A2 throughout the season ($P = 0.01$); there was no difference between treatments at C1 (Fig. 2). In 1985 there was no significant difference in the incidence or severity of flyspeck when averaged over all sites (Table 2). There was generally greater flyspeck incidence and severity in the pruned treatments at A2, and less in the pruned treatments at C1 and C2, but treatment differences were nonsignificant ($P = 0.05$) (Fig. 2, Table 4).

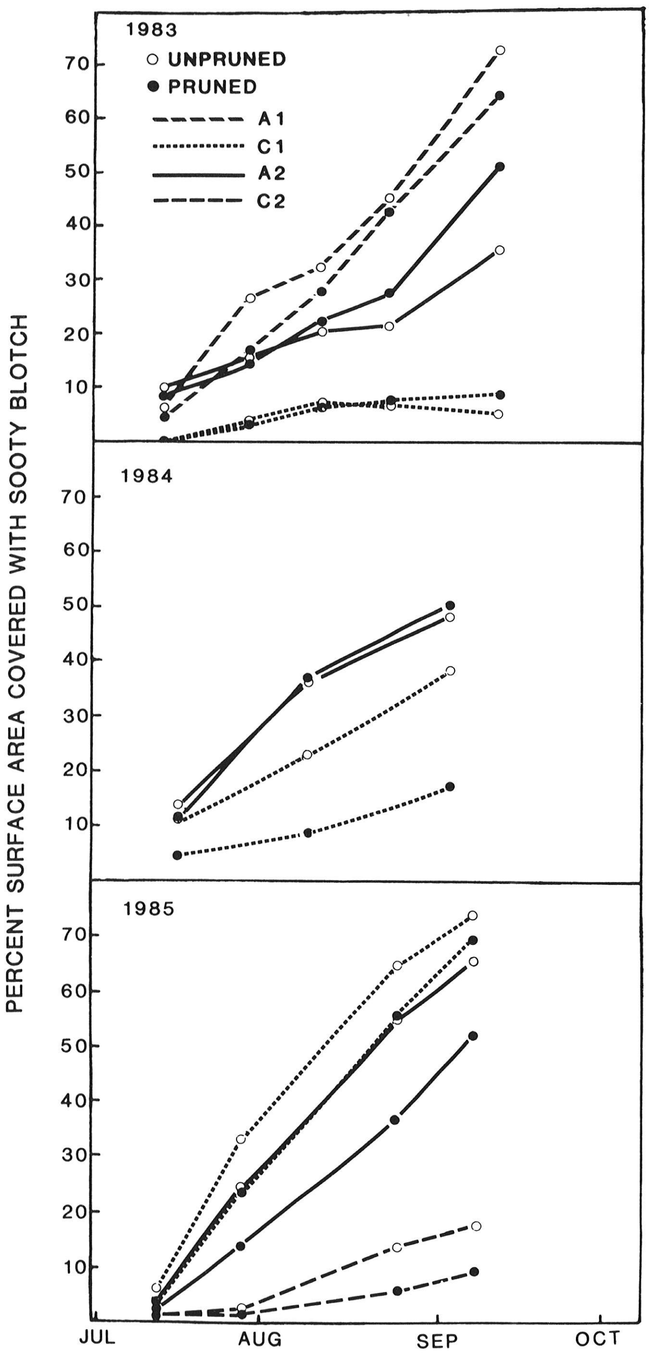

Fig. 1. Sooty blotch severity for 1983–1985.

DISCUSSION

Pruning of apple trees is practiced for modification of tree form for optimum production of high quality apples (1,2,8). Pruning enables management of tree shape, increased growth of fruiting spurs, improved fruit coloration, and management of disease by the removal of diseased stems and terminals or dead wood that can harbor pathogens. The selective removal of branches also increases air movement within the tree canopy, which facilitates quicker drying of plant surfaces and more uniform application of pesticides (1,7,18,23). Our data indicate that in seasons with normal or above-normal precipitation such as observed in 1984 and 1985, pruning can reduce the incidence and severity of sooty blotch. The effect of pruning on flyspeck incidence and severity was not clear. In 1984, the incidence and severity of flyspeck were significantly greater in the pruned treatment. However, there were no significant differences between the treatments in 1983 or 1985 although there was generally less disease in the pruned treatment in the two commercial orchards in 1985.

Differences in the effect of pruning on the two pathogens may be due to differences in their biology and epidemiology. Both pathogens infect numerous wild hosts, mainly trees and shrubs (3,5,9,11,18), which provide an inoculum reservoir. Pseudothecia of *S. pomi* and pycnidia of *G. pomigena* overwinter on wild hosts and apple twigs in the canopy (4,18). In the spring, ascospores of *S. pomi* are discharged during rain and are blown to hosts where they initiate primary infection. Secondary infections are initiated by airborne conidia, which are produced throughout the growing season. Because pruning reduces canopy density, fruit would be more exposed and accessible to airborne deposition. Thus, any influence of pruning on the duration of wetting, temperature, etc., might be offset by increased inoculum deposition. Conidia of *G. pomigena* are disseminated by wind-blown rain and initiate primary infection on apple twigs and fruit as well as wild hosts. Hyphal fragments or buds, disseminated by rain or dew, are the source of secondary inoculum. Thus, free moisture is necessary for dissemination, and pruning would have less effect on deposition.

Because *G. pomigena* and *Z. jamaicensis* superficially colonize the fruit surface, these fungi may be especially sensitive to environmental conditions for disease development. Rainfall and RH are considered among the most important environmental parameters for growth of the two fungi. Kirby (17) reported that the amount of sooty blotch in unsprayed orchards in Pennsylvania was proportional to the amount of rain occurring during July and, to a lesser extent, in August and September. However, the very low rainfall during July 1983 at A2 did not limit sooty blotch severity or flyspeck incidence that season, as final disease values were nearly the same in 1984. This may be due to the fact that the average daily period of high RH was of sufficient duration for sooty blotch and flyspeck development.

Cultural practices such as canopy architecture (6), row orientation (15), irrigation regime (6,21), and canopy management (22) have been shown to reduce the disease incidence and/or severity of diseases in other crops. However, for the most part, the

TABLE 4. Mean incidence of flyspeck at each site, 1983–1985

Year and Date	Percent fruit affected with *Zygophiala jamaicensis*[a]							
	A1[b]		A2		C1		C2	
	Unpruned	Pruned	Unpruned	Pruned	Unpruned	Pruned	Unpruned	Pruned
1983								
15 June	0	0	0	0	0	0	...	...
13 July	43	19**[c]	29	23	0	0	...	...
28 July	85	76	52	47	25	25	...	...
10 August	98	97	91	86	52	46	...	...
23 August	97	98	88	86	68	72	...	...
12 September	100	100	96	96	79	90	...	...
1984								
25 June	...	...	3	1	0	0	...	...
16 July	...	...	63	77	24	12	...	...
8 August	...	...	82	94	37	38	...	...
3 September	...	...	91	100	64	55	...	...
1985								
13 June	...	...	0	0	0	0	0	0
13 July	...	...	7	10	5	7	0	0
27 July	...	...	89	88	64	54	0	0
24 August	...	...	95	100	98	93	83	70
7 September	...	...	94	100	98	95	89	84

[a]Average based on 25 fruit per tree in 1983-1984 and 40 fruit in 1985; three replications were used each year.
[b]See text for description of orchards.
[c]** indicates significant differences between the two treatments on the date of assessment at $P = < 0.01$, as determined in an analysis of variance.

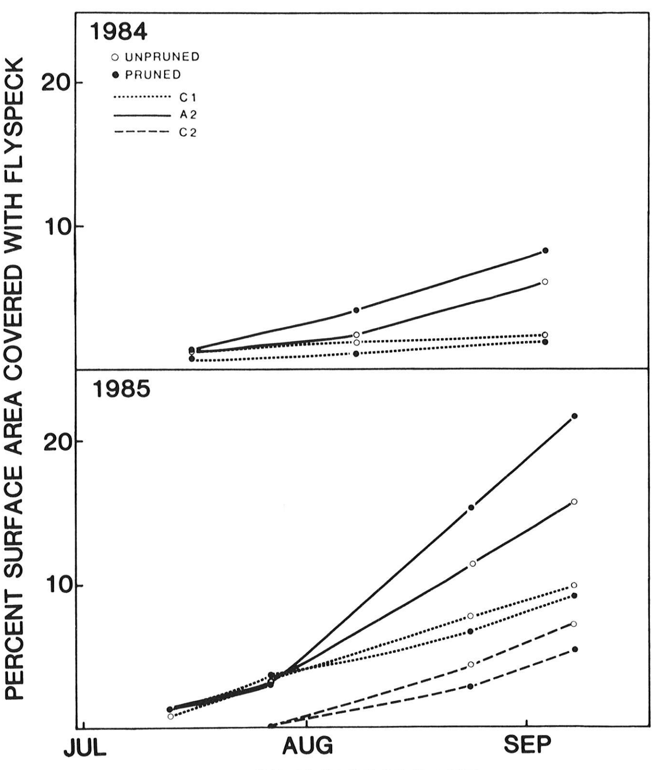

Fig. 2. Flyspeck severity for 1984–1985.

differences in disease incidence and severity have been difficult to explain based on measured differences in environmental factors such as temperature, relative humidity, or wetness duration. In this study there was no consistent difference between temperature and relative humidity as monitored by hygrothermographs placed in the canopies of pruned and unpruned trees. Savage and Sall (22) reported Botrytis fruit rot of grape to be 47% greater on vines trained on a cross-arm style trellis than vines trained to a two-wire vertical trellis. However, only subtle differences in temperature or moisture regimes were associated with the change in trellis type and a change in disease severity. They hypothesized that minor changes in air movement or light penetration in a grape cluster could alter the water vapor status at boundary layers in which fungal thalli exist before or during infection. It is possible that pruning alters the microclimate of apple fruit by increasing air movement and light penetration so as to decrease the length of the moisture period or high RH.

We could not demonstrate a consistent effect of pruning on the incidence or severity of flyspeck, and although sooty blotch incidence and severity were significantly less in pruned trees in 2 of the 3 yr, differences between treatments were not great. Thus, it is unlikely that pruning can account for the amount of disease reduction in pruned trees that we and others (9,18) have observed in commercial orchards. It is possible that the reduction in disease observed is primarily a result of more efficient fungicide deposition in pruned trees. Travis et al (24) found that deposition was greater and less variable on leaves in well-pruned trees than unpruned ones. Although deposit on fruit was not measured, it is reasonable to expect that it would be greater also. Thus, improved fungicide deposit probably accounts for most of the reduction in sooty blotch and flyspeck incidence and severity observed in well-pruned commercial orchards although microenvironmental effects on the pathogens may contribute to disease reduction, especially in wet years.

LITERATURE CITED

1. Anderson, H. W. 1956. Diseases of Fruit Crops. McGraw-Hill Book Co., Inc., New York. 501 pp.
2. Bailey, L. H. 1903. The Pruning-Book. Macmillan Co., New York. 545 pp.
3. Baines, R. C. 1940. Pathogenicity and hosts of the fly-speck fungus of apple. (Abstr.) Phytopathology 30:2.
4. Baines, R. C., and Gardner, M. W. 1932. Pathogenicity and cultural characters of the apple sooty-blotch fungus. Phytopathology 22:937-952.
5. Baker, K. F. 1977. Greasy blotch of carnation and flyspeck of apple: Diseases caused by *Zygophiala jamaicensis*. Phytopathology 67:580-588.
6. Blad, B. L., Steadman, J. R., and Wiess, A. 1978. Canopy structure and irrigation influence white mold disease and microclimate of dry edible beans. Phytopathology 68:1431-1437.
7. Chester, K. S. 1947. Nature and Prevention of Plant Diseases. Blakiston Co., Philadelphia. 525 pp.
8. Childers, N. F. 1961. Modern Fruit Science. Horticultural

Publications, New Brunswick, NJ. 891 pp.
9. Colby, A. S. 1920. Sooty blotch of pomaceous fruits. Trans. Ill. Acad. Sci. 13:139-179.
10. Duggar, B. M. 1909. Sooty blotch and fly speck of the apple and other plants. *Leptothyrium pomi* (Mont. & Fr.) Sacc. Pages 367-369 in: Fungous Diseases of Plants. Ginn & Co., Boston.
11. Durbin, R. D., Davis, L. H., Snyder, W. C., and Baker, K. F. 1953. The imperfect state of *Microthyriella rubi*, cause of flyspeck of apple. (Abstr.) Phytopathology 43:470.
12. Durbin, R. D., and Snyder, W. C. 1953. Flyspeck of apple in California. Plant Dis. Rep. 37:166.
13. Gardner, M. W., and Baines, R. C. 1931. Cultural characters and host range of the apple sooty-blotch fungus. Phytopathology 21:112.
14. Groves, A. B. 1933. A study of the sooty blotch disease of apples and causal fungus *Gloeodes pomigena*. Va. Agric. Exp. Stn. Bull. 50:1-43.
15. Haas, J. H., and Bolwyn, B. 1972. Ecology and epidemiology of Sclerotinia wilt of white beans in Ontario. Can. J. Plant Sci. 52:525-533.
16. Hickey, K. D. 1960. The sooty blotch and flyspeck diseases of apple with emphasis on variation within *Gloeodes pomigena* (Schw.) Colby. Ph.D dissertation. The Pennsylvania State University, University Park. 127 pp.
17. Kirby, R. S. 1954. Relation of rainfall to occurrence of apple scab and sooty blotch. (Abstr.) Phytopathology 44:495.
18. Latham, A. J., and Hollingsworth, M. H. 1973. Incidence and control of sooty blotch and flyspeck on apples in Alabama. Auburn Univ. Agric. Exp. Stn. Cir. 208. 11 pp.
19. Main, C. E., Essex, B. W., and Bragg, A. W. 1980. Crop Losses in North Carolina Due to Plant Diseases and Nematodes. Department of Plant Pathology. Special Publ. No. 1. NCSU, Raleigh. 106 pp.
20. Main, C. E., Essex, B. W., and Bragg, A. W. 1983. Crop Losses in North Carolina Due to Plant Diseases and Nematodes. Department of Plant Pathology. Special Publ. No. 2. NCSU, Raleigh. 167 pp.
21. Rotem, J., and Cohen, Y. 1966. The relationship between mode of irrigation and severity of tomato foliage disease in Israel. Plant Dis. Rep. 50:635-637.
22. Savage, S. D., and Sall, M. A. 1984. Botrytis bunch rot of grapes: Influence of trellis type and canopy microclimate. Phytopathology 74:65-70.
23. Sutton, T. B., and Unrath, C. R. 1984. Evaluation of the tree-row-volume concept with density adjustments in relation to spray deposits in apple orchards. Plant Dis. 68:480-484.
24. Travis, J. W., Skroch, W. A., and Sutton, T. B. 1987. Effect of canopy density on pesticide deposition and distribution in Golden Delicious apple trees. Plant Dis. 71:613-615.
25. Wormald, H. 1946. Diseases of Fruits and Hops. Crosby Lockwood & Son Ltd., London. 302 pp.

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