The Influence of the Apple Aphid/Spirea Aphid Complex on Intensity of Alternaria Blotch of Apple and Fruit Quality Characteristics and Yield

Nenad Filajdić, Former Graduate Research Assistant, Department of Plant Pathology, **T. B. Sutton**, Professor, Department of Plant Pathology, **J. F. Walgenbach**, Associate Professor, Department of Entomology, and **C. R. Unrath**, Professor, Department of Horticultural Science, North Carolina State University, Raleigh 27695-7616

ABSTRACT

Filajdić, N., Sutton, T. B., Walgenbach, J. F., and Unrath, C. R. 1995. The influence of the apple aphid/spirea aphid complex on intensity of Alternaria blotch of apple and fruit quality characteristics and yield. Plant Dis. 79:691-694.

Two levels of aphid densities (apple aphid/spirea aphid complex) were established within treatments of two levels of Alternaria blotch at two locations in 1992 and one in 1993. At the high disease level, disease severity was greater in treatments in which a high aphid density was present. Defoliation was increased at one location in 1 year. Fruit quality characteristics such as soluble solids content, diameter, and weight were often decreased at the high aphid density; firmness was increased and commercial color decreased in some cases. Yield was not affected by aphids.

Apple aphid (*Aphis pomi* DeGeer) and spirea aphid (*Aphis spiraecola* Patch) are common pests in apple (*Malus* × *domestica* Borkh.) orchards in the southeastern United States. The two species are morphologically similar and difficult to distinguish in the field (8). Both species are considered to have minimal effect on growth and yield of bearing Red Delicious trees (2); both species, however, negatively affect growth and leaf formation of young trees (3,4,5). For orchard management purposes, the two species are not distinguished and action thresholds for the aphid complex are used (5).

Both species feed on apple leaves with their piercing-sucking mouth parts and remove phloem sap, generally from growing shoot tips where the nutritive quality is highest. In North Carolina, apple aphid populations are most intense during May through July.

Feeding by European red mite (ERM) *Panonychus ulmi* (Koch) increases severity of Alternaria blotch (*Alternaria mali*, Roberts) and defoliation, and reduces yield and fruit quality when high mite populations are present (1). Integrated Pest Management (IPM)–based strategies for management of Alternaria blotch must be designed within the context of established insect and mite management programs. Therefore, the objective of this study was to determine if apple aphid/ spirea aphid feeding on apple leaves increases the intensity of Alternaria blotch on Delicious apple, and if fruit quality characteristics and yield are affected.

MATERIALS AND METHODS

Description of orchards and the experimental design. Two commercial orchards in western North Carolina (McKay and Staton), planted to Oregon Spur Delicious, 12 and 8 years old, respectively, were used in this study. The McKay orchard has a history of severe Alternaria blotch from 1989 to 1993 with up to 70% defoliation, whereas at the Staton orchard Alternaria blotch was of moderate intensity from 1990 to 1992, and was severe in 1993.

Four treatments (two levels of Alternaria blotch × two aphid densities) were established in three replicate randomized complete blocks at both locations. The low level of Alternaria blotch was established by spraying trees with 0.6 g a.i. per liter of iprodione (Rovral 4F) to the drip point, using a Swanson DA 500 speed sprayer (Durand Wayland, LaGrange, Ga.) driven at 4 km per h and with 1,379 kPa manifold pressure. The spray program was initiated on 15 May of each year and continued on a 2-week schedule until 4 August 1992 and 27 August 1993. Aphid levels were managed with applications of phosphamidon (Phosphamidon 8E) at 93.5 g a.i. per ha. Treatments in which a low aphid population was desired were sprayed preventively on 13 May, 2, 10, and 17 June, and 7 July 1992, and on 21 May, 11 June, and 2 July 1993. Aphid populations were monitored weekly beginning on 29 April 1992 and 17 May 1993 and continuing until 27 July 1992 and 26 July 1993. No phosphamidon applications were sprayed in the high aphid density treatment. In addition, ERM populations were managed with applications of propargite (Omite 30WP) at 0.72 g a.i. per liter on 10 June, 7 and 21 July 1992, and 2 and 11 July 1993. Propargite was applied to drip with a handgun sprayer.

Two methods were used to assess aphid densities: in 1992, 10 terminals per tree were arbitrarily selected on each assessment date and the number of terminals with ≥1 apterous aphid was recorded. Aphid populations in each treatment were expressed as area under curve (AUC), which was calculated by summing the product of the percent terminals infested with aphids for each sampling date by number of days between two sampling dates. In 1993, terminals were selected in the same manner as in 1992, but number of leaves per terminal infested with aphids was recorded. Aphid infestation in each treatment was expressed as AUC, which was calculated by summing the product of mean number of leaves per terminal infested with aphids for each sampling date by number of days between two sampling dates. Number of ERM was assessed on 10 arbitrarily selected leaves per tree using a magnifying visor (Optivisor magnifier, Donegan Optical Company Inc., Lenexa, Kans.) on the same days that aphid populations were assessed.

Alternaria blotch severity was assessed on all leaves from 10 and four arbitrarily selected terminals per tree in 1992 and 1993, respectively. Terminals were selected and tagged 2 weeks before the first disease assessment in each year; the same terminals were evaluated on each assessment date. The lower portion of the Horsfall-Barratt scale of 0 to 5 was used, in which 0 = no lesions, 1 = 1 to 3% leaf area covered with lesions, 2 = 4 to 6%, 3 = 7 to 12%, 4 = 13 to 25%, and 5 = 26 to 50%. Disease severity was assessed on 19 May, 3, 15, and 29 June, 14 and 30 July, 18 August, and 4 September 1992, and on 20 May, 10 and 24 June, 8 and 22 July, 12 and 26 August, and 14 September 1993. Defoliation was assessed using the same

Present address of first author: ZENECA Ag Products, Eastern Regional Technical Center, Route One, Box 117, Whitakers, N.C. 27891.

Present address of second author: Department of Plant Pathology, University of California, Davis 95616.

The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Service nor criticism of similar ones not mentioned.

Accepted for publication 27 February 1995.

terminals on the last four sampling dates in each year. The number of nodes where leaves had abscised and the total number of nodes on a terminal were counted and percent defoliation was calculated.

Fruit drop. Number of fruit beneath each tree was recorded at harvest of each year (10 September 1992 and 21 September 1993) and percent fruit drop was calculated by dividing the number of fallen fruit by the total number of fruit remaining on each tree plus the number of drops and multiplying by 100.

Fruit quality. Twenty fruit were collected arbitrarily from each tree at harvest in each year and brought to the laboratory. Measurements of diameter, firmness, commercial color, soluble solids content, and weight were recorded. Fruit diameter at the equator was measured using a hand-held band-sizer (Cranston Machinery Co., Oak Grove, Oreg.); firmness was assessed with a hand-held pressure tester (McCormick Fruit Tech Co., Yakima, Wash.); soluble solids content was measured with a refractometer (American Optical, Scientific Instrument Division, Buffalo, N.Y.); and commercial color was calculated from a visual assessment of percent total and red color to the nearest 5%, using the formula CC = RC + ((TC - RC) / 2), where CC = commercial color, RC = percent red color, and TC = percent total color.

Yield. Yield for each tree was estimated by multiplying the number of fruit remaining on each tree at harvest by mean fruit weight.

Statistical analysis. All data were analyzed as a 2 × 2 factorial experiment using the PROC ANOVA procedure of the Statistical Analysis System (SAS Institute, Cary, N.C.).

Table 1. Area under curve (AUC) in 1992[x]

Year and treatment[y]	AUC McKay	AUC Staton
1992		
LD-LA	163.0 d[z]	205.2 d
LD-HA	386.4 b	387.2 b
HD-LA	219.3 c	253.2 c
HD-HA	425.1 a	434.7 a
1993		
LD-LA	49.6 d	60.0 NS
LD-HA	94.8 b	83.9
HD-LA	65.8 c	56.8
HD-HA	105.0 a	79.0

[x] AUC was calculated by adding the product of mean number of terminals (out of selected 10 terminals) infested with aphids for each sampling date by number of days between two sampling dates.

[y] LD = low disease level, LA = low aphid level, HA = high aphid level, HD = high disease level.

[z] Numbers within column followed by different letters are significantly different (P = 0.05), according to the Waller-Duncan k-ratio t test. NS = not significant.

RESULTS

Aphid and ERM populations. In 1992, the number of terminals infested with aphids steadily increased from 29 April until 22 June at both locations. After that date, aphid populations decreased rapidly. Number of aphid-infested terminals (expressed by AUC) in treatments in which a high density was desired was significantly greater than the number of aphid-infested terminals in the low density treatments (Table 1).

In 1993, at both locations, the number of leaves per terminal infested with aphids increased from 17 May until 28 June, after which populations decreased. At McKay, the AUC was higher in the high than low aphid density treatments; however, at Staton differences were not significant (P = 0.05) (Table 1). Therefore, only data from McKay in 1992 and 1993 and Staton in 1992 for disease severity, defoliation, fruit drop, fruit quality, and yield are presented. Number of ERM per leaf was not different for any of the treatments used in this study in either location or year.

Disease severity. At the McKay and Staton orchards in 1992, disease severity was greater in treatments with a high aphid density than in those with a low aphid density among treatments within the same disease level on the last three sampling dates (Fig. 1A and C). In 1993, severity was greater in treatments with a high aphid density within the same disease levels except the difference in the low density level was not significant on 14 September (P = 0.05) (Fig 1B).

Defoliation. At the McKay orchard in 1992, at both disease levels, defoliation was greater in treatments with a high aphid density (Fig. 2A). Defoliation was considerably less in 1993 than in 1992. Generally, there were no differences detected among treatments except on the last sampling date, when greater defoliation was recorded in the treatment with a high disease level and a high aphid density than in the treatment with high disease and a low aphid density (Fig. 2B).

At the Staton orchard, there were no differences in defoliation among treatments within the same disease level, except on 4 September 1992, when greater defoliation was recorded in the treatment with a low disease level and a high aphid density than in the treatment with a low disease level and a low aphid density (Fig. 2C).

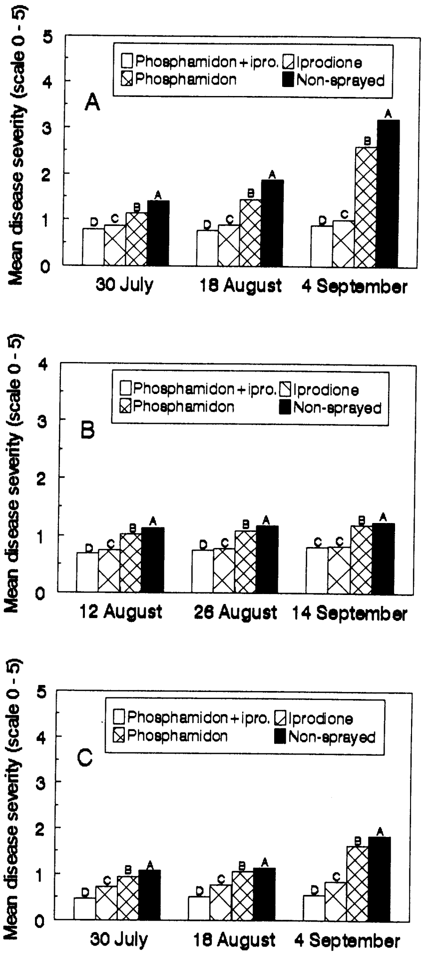

Fig. 1. Mean disease severity obtained using a lower portion of the Horsfall-Barratt scale of 0 to 5, for four treatments on the three last sampling dates. **(A)** McKay 1992, **(B)** McKay 1993, **(C)** Staton 1992.

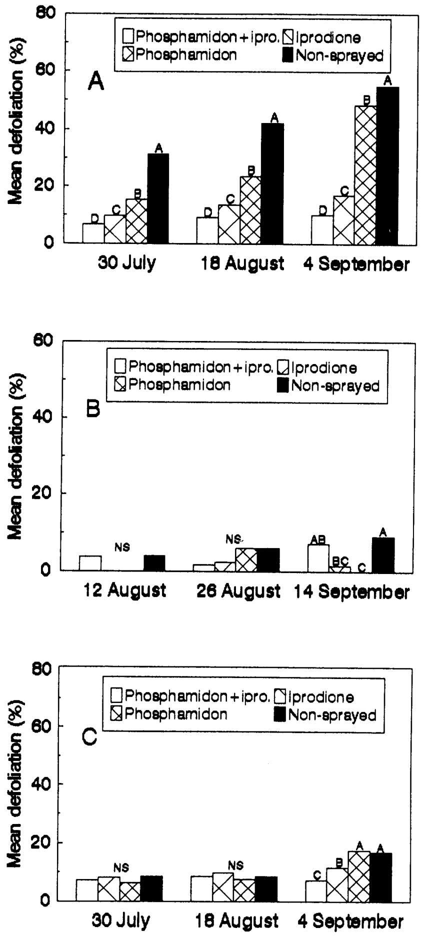

Fig. 2. Mean percent defoliation for four treatments on three last sampling dates. **(A)** McKay 1992, **(B)** McKay 1993, **(C)** Staton 1992.

Fruit quality characteristics. *Diameter.* Diameter was reduced in both disease levels by high aphid densities at McKay in 1993 and in the high disease level at Staton in 1992. At McKay in 1992, diameter increased with a high aphid density in treatments with a low disease level (Table 2).

Firmness. Firmness was reduced in both disease levels by the high aphid density at McKay in 1992. It increased with a high aphid density in treatments with a high disease level at McKay 1993. Firmness was not affected in other instances (Table 2).

Commercial color. Commercial color within disease levels was not affected in either year or location (Table 2).

Soluble solids content. Soluble solids content was less at the high aphid density in treatments with both disease levels at McKay 1992 and in treatments with high disease level at McKay 1993. At Staton, soluble solids content increased at the high aphid density in treatments with both disease levels (Table 2).

Weight. Weight decreased in treatments with a high aphid density at McKay in 1993 within both disease levels and increased at high disease level at Staton in 1992. There were no significant differences among treatments at McKay in 1992 (Table 2).

Fruit drop. Preharvest fruit drop increased with high aphid density in treatments with low disease at McKay 1992, and in treatments with both disease levels at McKay 1993. However, it decreased with high aphid density in treatments with high disease at McKay and Staton in 1992 (Table 3).

Yield. Yield within the same disease levels was not affected by aphid feeding except for McKay 1993 when it increased with aphid density in treatments with high disease (Fig. 3A, B, and C).

Table 2. Fruit quality and yield characteristics associated with three aphid population levels and two levels of Alternaria blotch at different locations and years

Fruit characteristic	Treatment[y] LD-LA	LD-HA	HD-LA	HD-HA
McKay 1992				
Diameter (cm)	6.5 b[z]	6.8 a	6.5 b	6.6 b
Firmness (N/cm^2)	81.1 a	76.9 b	74.8 c	73.1 d
Commercial color	46.4 b	46.7 b	47.1 ab	48.1 a
Soluble solids (%)	13.0 a	12.6 b	12.8 ab	12.3 c
Weight (g)	131.2	145.9	130.2	135.5 NS
McKay 1993				
Diameter (cm)	6.7 a	6.5 c	6.6 b	6.4 c
Firmness (N/cm^2)	72.1 a	70.5 a	66.9 b	70.9 a
Commercial color	49.0 a	48.6 a	46.6 b	46.5 b
Soluble solids (%)	12.6 a	12.4 ab	12.3 b	12.0 c
Weight (g)	124.2 a	109.9 c	117.3 b	108.3 c
Staton 1992				
Diameter (cm)	7.1 b	7.0 b	7.4 a	7.1 b
Firmness (N/cm^2)	74.3 a	72.7 ab	72.3 b	74.1 ab
Commercial color	49.8	49.3	50.8	50.0 NS
Soluble solids (%)	12.6 b	13.0 a	12.6 b	12.9 a
Weight (g)	167.7 b	161.0 b	182.4 a	160.5 b

[y] The abbreviations in treatment column: LD = low disease level, LA = low aphid level, HA = high aphid level, and HD = high disease level.

[z] Numbers within row followed by different letters are significantly different ($P = 0.05$), according to the Waller-Duncan k-ratio t test. NS = not significant.

Table 3. Percent preharvest fruit drop associated with two aphid population levels and two levels of Alternaria blotch at different locations and years

Location	Year	Treatment[x]	Percent fruit drop[y]
McKay	1992	LD-LA	4.4 d[z]
		LD-HA	8.2 c
		HD-LA	19.8 a
		HD-HA	18.0 b
McKay	1993	LD-LA	6.3 d
		LD-HA	8.8 c
		HD-LA	11.2 b
		HD-HA	11.8 a
Staton	1992	LD-LA	11.0 b
		LD-HA	9.7 b
		HD-LA	53.2 a
		HD-HA	25.4 b

[x] LD = low disease level, LA = low aphid level, HA = high aphid level, and HD = high disease level.

[y] Percent fruit drop recorded on 9 September 1992 and 21 September 1993 at the McKay and Staton orchards.

[z] Numbers within column followed by different letters are significantly different ($P = 0.05$), according to the Waller-Duncan k-ratio t test.

DISCUSSION

In this study, Alternaria blotch severity increased with high aphid density in most of the tests conducted. Effects on defoliation were not as great although defoliation increased in both disease levels at one location in 1992. Aphids did not negatively affect yield although fruit diameter and weight were decreased in some treatments. Commercial color was not affected but soluble solids were reduced in one-half of the tests.

Aphid feeding did not influence fruit quality and yield of Red Delicious (2) or accumulation of dry weight of young trees in previous reports (10). However, Kaakeh et al. (3,4,5), found that aphids reduced net photosynthesis, greenness, accumulation of fresh and dry weights, lateral shoot growth, and percentage and amount of nonstructural carbohydrates in greenhouse experiments. Varn et al. (10) hypothesized that the density achieved in their study, 65 aphids per leaf, might have been too low to affect the trees. We did not attempt to quantify number of aphids per leaf, but instead expressed aphid populations as percent terminals infested in 1992 and number of infested leaves per terminal in

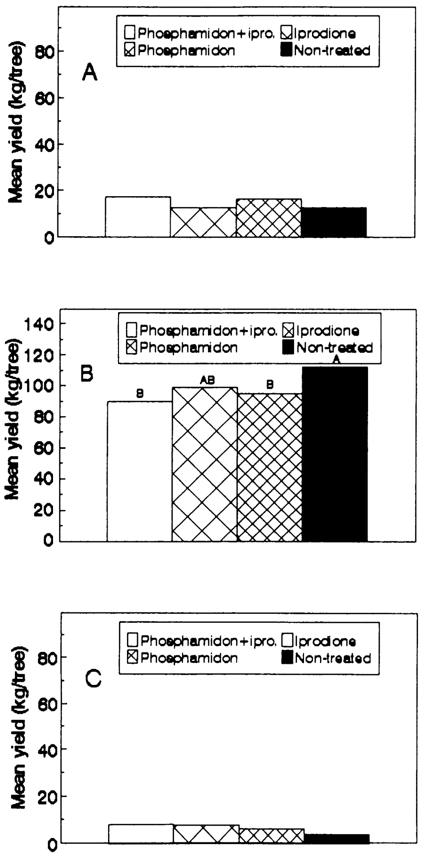

Fig. 3. Yield for each tree calculated by multiplying the mean number of fruit remaining on tree at harvest by mean fruit weight. **(A)** McKay 1992, **(B)** McKay 1993, **(C)** Staton 1992.

1993. Both of these methods are rapid but at the same time have disadvantages. With the first method, when 10 terminals per tree were selected, the number of aphid-infested terminals approached 10 when aphid populations were high (mid-June). At that time, the method was not sensitive enough to detect differences among treatments, although differences may have been detected if number of aphids per terminal had been counted. When the number of aphid-infested leaves per terminal was used, variation increased because of different numbers of leaves on different terminals. This method is more sensitive but also more time-consuming. Consistent criteria are needed to quantify aphid populations for future studies.

Based on results reported by Hamilton et al. (2) and Varn et al. (10), Pfeiffer (7) concluded that control of summer populations of the green apple aphid/spirea aphid complex on bearing Red Delicious trees is probably not justified. This conclusion was made with respect to the currently recommended threshold of 50% infested terminals (6,9), which was arbitrarily defined with no consideration of population effects on shoot growth, fruit quality, and yield (7). Our data support Pfeiffer's conclusion that control of aphid populations should not be based on a threshold of 50% infested terminals. On the other hand, our findings indicate that aphid populations cannot be ignored. Although yield was not negatively affected, aphid infestations lowered fruit quality. Furthermore, severity of Alternaria blotch and defoliation were greater when aphid populations were left uncontrolled. In other studies, we found a very good correlation between Alternaria blotch severity and defoliation (N. Filajdic and T. B. Sutton, *unpublished*). Based on our studies, we believe that the action threshold can be increased from 50 to 100% infested terminals in Red Delicious orchards where Alternaria blotch is not a problem. However, aphid populations should not be allowed to continue to increase once 100% infestation has occurred.

Effects of aphids on intensity of Alternaria blotch, defoliation, and fruit quality were not as great as those caused by European red mites (1), which need to be maintained at or below current IPM thresholds until an effective fungicide is registered for Alternaria blotch control. However, aphid populations should not be left uncontrolled if there are no fungicidal controls for Alternaria blotch, and the current threshold level of 50% infested terminals would minimize the effects of Alternaria blotch on fruit quality parameters and yield.

ACKNOWLEDGMENTS

We thank Charles Palmer, J. D. Obermiller, and Ray Pope for technical assistance.

LITERATURE CITED

1. Filajdić, N., Sutton, T. B., Walgenbach, J. F., and Unrath, C. R. 1995. The influence of European red mites on intensity of Alternaria blotch of apple and fruit quality and quantity characteristics. Plant Dis. 683-690.
2. Hamilton, G. C., Swift, F. C., and Marini, R. 1986. Effect of *Aphis pomi* (Homoptera: Aphididae) density on apples. J. Econ. Entomol. 79: 471-478.
3. Kaakeh, W., Pfeiffer, D. G., and Marini, R. P. 1992. Combined effects of spirea aphid (Homoptera: Aphididae) and nitrogen fertilization on shoot growth, dry water accumulation, and carbohydrate concentration in young apple trees. J. Econ. Entomol. 85:496-506.
4. Kaakeh, W., Pfeiffer, D. G., and Marini, R. P. 1992. Combined effects of spirea aphid (Homoptera: Aphididae) and nitrogen fertilization on net photosynthesis, total chlorophyll content, and greenness of apple leaves. J. Econ. Entomol. 85:939-946.
5. Kaakeh, W., Pfeiffer, D. G., and Marini, R. P. 1993. Effect of *Aphis spiraecola* and *Aphis pomi* (Homoptera: Aphididae) on the growth of young apple trees. Crop Protect. 12:141-147.
6. Madsen, H. F., Peters, H. F., and Vakenti, J. M. 1975. Pest management experience in six British Columbia apple orchards. Can. Entomol. 107:873-877.
7. Pfeiffer, D. G. 1991. Biology and Management of Aphids on Apple. Pages 169-183 in: New Directions in Tree Fruit Pest Management. Kathleen Williams, ed. Good Fruit Grower, Yakima, Wash.
8. Pfeiffer, D. G., Brown, M. W., and Varn, M. W. 1989. Incidence of spirea aphid (Homoptera: Aphididae) in apple orchards in Virginia, West Virginia, and Maryland. J. Entomol. Sci. 24:145-149.
9. Prokopy, R. J., Coli, W. M., Hislop, R. G., and Hauschild, K. I. 1980. Integrated pest management of insect and mite pests in commercial apple orchards in Massachusetts. J. Econ. Entomol. 73:529-535.
10. Varn, M., and Pfeiffer, D. G. 1989. Effect of rosy apple aphid and spirea aphid (Homoptera: Aphididae) on dry matter accumulation and carbohydrate concentration in young apple trees. J. Econ. Entomol. 82:565-569.