Reduced Midseason Pesticide Program for Control of Scab and Plum Curculio in Peach

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ABSTRACT

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Risks to peach production from scab (caused by *Cladosporium carpophilum*) and plum curculio (*Conotrachelus nenuphar*), two key pests in the southeastern United States, are high until 2 months past petal fall and then decreases during midseason. This suggests that reduced-input pesticide strategies may effectively control both pests during the latter period. In this study, we evaluated midseason pesticide applications according to an alternate-row middle (ARM) spray program in which sprays were applied only to every other tree row while reducing tractor speed and keeping application intervals unchanged relative to conventional spraying of both sides of the trees. In a 2-year trial in a research orchard, conventional sprays of fungicide (primarily sulfur) and insecticide (primarily phosmet) were applied at 10- to 14-day intervals until first cover, followed by continued conventional sprays of fungicide and insecticide (standard), conventional sprays of one pesticide together with ARM sprays of the other pesticide, or combined ARM sprays of both pesticides. Schedules with midseason ARM sprays of both pesticides also were evaluated in two commercial orchards in 2 years. In all experiments, plots receiving combined ARM sprays were equivalent to the standard in fruit quality and control of scab and plum curculio. Combined ARM spraying resulted in lower environmental nontarget effects (as estimated by the Environmental Impact Quotient) and reduced application time by 25 to 33% for each midseason spray and 12.5 to 18.5% for the entire period from petal fall to the preharvest interval.

Additional keywords: integrated pest management, *Prunus persica*

Peach (*Prunus persica*) and related stone fruits are important horticultural commodities in the southeastern United States. In 2000, Georgia and South Carolina together produced approximately 120 million kg of peaches valued at \$70 million (2). Due to the region's long, warm, and humid growing season, pest populations can build up rapidly and threaten profitable peach production. *Cladosporium carpophilum* (the fungus causing scab) and *Conotrachelus nenuphar* (plum curculio) are two key peach pests in the Southeast (11,14,17,21, 27,30). Fruit infection by *C. carpophilum* causes dark, raised lesions that reduce fruit quality and may cause cracking, thereby increasing susceptibility to fruit rot pathogens. Plum curculio adults feed on and oviposit in young, developing fruit, thereby causing conspicuous scarring and subsequent fruit malformation (14). If oviposition occurs at later stages of fruit development and mature fruit are infested with plum curculio larvae, affected fruit loads

become unmarketable. In Georgia in 1997, losses in peach were estimated at \$3.2 million from scab and \$1.8 million from plum curculio (3,13).

Peach pest management in the southeastern United States is based primarily on calendar-based fungicide and insecticide programs empirically adjusted for farm and region (15,22). In most instances, insecticide and fungicide applications are made at 7- to 14-day intervals from petal fall or calyx split until harvest. Because peach is almost exclusively a fresh-market commodity, frequent pesticide use results not only in high cost for producers, but also in increased risk of nontarget effects. Recent field studies in Georgia indicated that a midseason alternate-row middle (ARM) spray program of fungicides can effectively reduce fungicide input while controlling scab as effectively as a standard program with fungicides applied conventionally to both sides of the trees (26). With the ARM method, pesticides are sprayed only in every other row middle, alternating tree rows at each successive spray event. The concept of ARM spraying was originally developed against apple pests in Pennsylvania (19) and subsequently evaluated and adopted on apple in other northeastern states (10,24). Spray intervals used for ARM applications generally are shorter than those used for conven-

tional spraying (10,19,24); however, in the peach scab study cited above (26), ARM application intervals remained unchanged relative to conventional spraying while compensating by reducing tractor speed to increase spray coverage.

ARM spraying offers the potential for reductions in pesticide use while, at the same time, providing effective pest control. In peach, the synchronous life histories of the scab fungus and the plum curculio suggest that it may be possible to apply combined ARM sprays of fungicide and insecticide against both pests. Release of conidia of *C. carpophilum* from twig lesions, which serve as the sole source of primary inoculum (17), peaks between petal fall and calyx fall (6,17); this same period marks the peak appearance of overwintered plum curculio adults in the orchard (14,27,30). Conventional applications of fungicide and insecticide during this high-risk period can reduce inoculum density of the scab fungus and prevent oviposition by the plum curculio. During midseason, the senescing of twig lesions during prevailing hot weather reduces spore production potential of *C. carpophilum* (6,17); at the same time, emergence of overwintered plum curculio adults approaches zero (27). In managed orchards, insecticides are applied rigorously from petal fall to calyx fall to preclude in-orchard reproduction, which reduces the risk of fruit injury from the field generation of plum curculio in June and July. Because the periods of heaviest pressure from scab and plum curculio occur early in the season, and the risk from both pests decreases from midseason to preharvest, a synchronized pesticide schedule may be appropriate for these pests. This could include use of reduced-input pesticide strategies such as ARM spraying during midseason when scab and plum curculio pressures are typically reduced.

The objectives of this study were to (i) evaluate the effectiveness of combined midseason ARM sprays of fungicide and insecticide in reducing fruit scab and plum curculio injury in research and commercial orchards; (ii) assess the economics of combined ARM spraying by examining fruit quality and reductions in application time compared with conventional spraying; and (iii) estimate reductions in environmental nontarget effects by calculating the Environmental Impact Quotient (18) associated with pesticide applications accord-

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ing to the conventional and ARM spray strategies.

MATERIALS AND METHODS

Research orchard. Field experiments were carried out on mature peach trees cv. Blake in 1999 and 2000 at the University of Georgia Horticulture Farm near Athens. Trees averaged ca. 2.2 m in height and were spaced 3.0 m within rows and 6.1 m across rows. Each year, the experiment consisted of seven treatments with four replications in a randomized complete block design. Individual plots were four trees long and five rows wide. Plots were rerandomized in the second year.

The seven treatments were: (i) untreated control that received no fungicide or insecticide; (ii) standard treatment receiving conventional sprays of fungicide (starting at calyx split) and insecticide (starting at petal fall); (iii) conventional sprays of fungicide, no insecticide; (iv) conventional

sprays of insecticide, no fungicide; (v) similar to treatment 2 except insecticide applications after first cover were made as ARM sprays; (vi) similar to treatment 2 except fungicide applications after first cover were made as ARM sprays; and (vii) similar to treatment 2 except applications of both pesticides after first cover were made as ARM sprays. Application schedules are summarized in Table 1.

Pesticide applications were made with an airblast sprayer (Model DA500CUD; Durand-Wayland Inc., LaGrange, GA) at a pressure of 1,035 kPa and a speed of 2.5 (conventional sprays) or 1.9 (ARM sprays) km h⁻¹ resulting in water volumes of 560 and 370 liters ha⁻¹, respectively. The primary fungicide and insecticide were sulfur (Yellow Jacket Wettable Dusting Sulfur, 90% a.i.) and phosmet (Imidan 70W, 70% a.i.), respectively. Captan (Captan 50WP, 48.9% a.i.) was used instead of sulfur at calyx split and calyx fall in 1999 and at

calyx split in 2000. In 1999, methyl-parathion (PennCap-M, 20.9% a.i.) was alternated with phosmet, whereas in 2000, no methyl-parathion was used due to label changes. Application rates are given in Table 1.

Commercial orchards. In 1999 and 2000, additional experiments were carried out in two commercial orchards in central Georgia on mature peach trees cv. Sunprince and O'Henry. Only two treatment strategies were compared: (i) season-long conventional sprays of fungicide and insecticide according to the producer's schedule; and (ii) conventional sprays of fungicide and insecticide until second cover, followed by ARM sprays of both pesticides in subsequent applications. Application timing for the two strategies was identical. Treatments were arranged in large (12 rows wide by entire length of the orchard), unreplicated blocks; replications for statistical analysis were obtained by considering the design a randomized complete block with four blocks (2 cultivars × 2 years). Application schedules are summarized in Table 2.

Pesticide applications were made with an airblast sprayer at a speed of 1.9 (conventional sprays) and 1.2 (ARM sprays) km h⁻¹ resulting in water volumes of 560 and 420 liters ha⁻¹, respectively. As in the research orchard, the primary pesticides were sulfur and phosmet. In 1999, captan replaced sulfur in two sprays in 'O'Henry', and methyl-parathion replaced phosmet in two sprays in 'O'Henry' and in one spray in 'Sunprince'. Application rates are given in Table 2.

Disease and insect damage assessment. Fruit scab severity and plum curculio damage incidence were assessed at the firm-ripe stage of fruit development on a random sample of 120 fruit per plot. In the research orchard, fruit were collected from the inside six trees of each plot. Scab severity was determined as percent scabbed surface area on individual fruit. Plum curculio damage incidence was based on the

Table 1. Pesticide programs for control of peach scab (caused by *Cladosporium carpophilum*) and plum curculio (*Conotrachelus nenuphar*) in a research peach orchard cv. Blake in 1999 and 2000^a

Treatment strategy	Application timing			
	Petal fall	Calyx split and calyx fall ^{b,c}	First cover ^b	Subsequent midseason sprays ^{b,d}
1	...	...	...	...
2	Phosmet	Phosmet Captan	Phosmet Sulfur	Phosmet Sulfur
3	...	Captan	Sulfur	Sulfur
4	Phosmet	Phosmet	Phosmet	Phosmet
5	Phosmet	Phosmet Captan	Phosmet Sulfur	ARM phosmet Sulfur
6	Phosmet	Phosmet Captan	Phosmet Sulfur	Phosmet ARM sulfur
7	Phosmet	Phosmet Captan	Phosmet Sulfur	ARM phosmet ARM sulfur

^a Phosmet was applied at 1.5 kg a.i. ha⁻¹, captan at 2.8 kg a.i. ha⁻¹, and sulfur at 10.1 kg a.i. ha⁻¹. In 1999, sulfur alternate-row middle (ARM) sprays from the fourth to sixth covers were applied at 15.1 kg a.i. ha⁻¹. On each application date, fungicide and insecticide were applied in different sprayer passes within a few hours of each other.

^b In 1999, phosmet was alternated with methyl-parathion (0.55 liters a.i. ha⁻¹) throughout the season. Methyl-parathion was not used in 2000 due to label changes.

^c In 2000, at calyx fall, sulfur was used instead of captan.

^d There were five and four midseason sprays in 1999 and 2000, respectively.

Table 2. Pesticide programs for control of peach scab (caused by *Cladosporium carpophilum*) and plum curculio (*Conotrachelus nenuphar*) in two commercial peach orchards in 1999 and 2000^a

Cultivar and year	Application timing					
	Petal fall	Calyx split	Calyx fall	First cover	Second cover	Subsequent midseason sprays ^{b,c}
Sunprince 1999	...	...	Methyl-parathion Sulfur	Methyl-parathion Sulfur	Phosmet Sulfur	Methyl-parathion ^d Sulfur
2000	Phosmet Sulfur	Phosmet Sulfur	...	Phosmet Sulfur	Phosmet Sulfur	Phosmet
O'Henry 1999	...	Methyl-parathion Sulfur	...	Methyl-parathion Sulfur	Phosmet Sulfur	Methyl-parathion ^d Sulfur
2000	...	Phosmet	Phosmet Sulfur	Phosmet Sulfur	...	Phosmet Sulfur

^a Phosmet was applied at 1.5 kg a.i. ha⁻¹, sulfur at 10.1 kg a.i. ha⁻¹, and methyl-parathion at 0.55 liters a.i. ha⁻¹.

^b Treatments were applied to large, unreplicated blocks as conventional sprays (to both sides of the trees) or as alternate-row middle (ARM) sprays.

^c In 'Sunprince', four midseason sprays were made in both years. In 'O'Henry', five and three such applications were made in 1999 and 2000, respectively.

^d Phosmet was used instead of methyl-parathion in selected sprays.

percentage of fruit with feeding scars, oviposition scars, and/or larval tunneling. Means and standard errors were calculated based on four replicates per treatment.

Fruit quality. All sampled fruit were classified individually as “Fancy”, “U.S. No.1”, or “U.S. No.2” based on quality criteria for scab and insect damage used in the United States Department of Agriculture’s grading standards for peaches (1). Fruit with larvae or larval exit holes were classified as “Wormy”; loads containing such fruit are unmarketable.

Environmental and economic impacts.

The potential environmental impact associated with pesticide use according to the various treatment strategies was evaluated using the Environmental Impact Quotient (EIQ) developed by Kovach et al. (18). EIQ values for each pesticide are based on the active ingredient’s potential effects on the health of farm workers and consumers and on potential adverse effects on groundwater quality and on nontarget aquatic and terrestrial organisms. For each spray application, the EIQ value of the pesticide (18) was multiplied by the concentration of active ingredient and by its application rate. Total potential impact was calculated by summing EIQ values for all applications from petal fall to the preharvest interval for each treatment.

Economic impacts were expressed as reductions in spray application time for the ARM method compared with conventional spraying. The calculations considered the fact that with ARM spraying only every other tree row was sprayed while tractor operation speed was reduced at the same time. Potential time savings associated with less frequent refilling of the sprayer were not included. Time savings over the entire season from petal fall to the preharvest sprays were expressed as a percentage of the total time used in the standard treatment (season-long conventional sprays).

Overwintered inoculum. At petal fall in late March or early April, conidial inoculum density on twig lesions formed during the experiments in the previous summer was determined in research and commercial orchards. This was done to determine whether the ARM fungicide programs might lead to a buildup of primary inoculum available for the following year. In the research orchard, 10 randomly selected 20-cm-long, 1-year-old twig segments were excised from the three rows in the center of each plot. In the two commercial orchards, each plot was divided into three or four strata, and 10 such twig segments were collected from each stratum. In the laboratory, twigs were misted with distilled water and incubated in moist chambers for 24 h to induce sporulation by *C. carpophilum*. Twig samples were processed as described previously (6,26), and the density of overwintered inoculum was expressed as number of conidia per cm of twig.

Statistical analysis. Fruit scab severity, plum curculio damage incidence, and overwintered inoculum density from the research orchard experiments were analyzed by analysis of variance (ANOVA) for a randomized complete block design (RCB), and means were separated by a multiple *t* test at $\alpha = 0.05$ (SAS version 8.02; SAS Institute, Inc., Cary, NC). Results from the commercial orchards were analyzed similarly after data from the 2 years and two cultivars had been combined, resulting in a RCB design with four blocks.

RESULTS

Scab severity. In the research orchard, scab severity in the untreated control was approximately eight times higher in 1999 than in 2000, most likely due to a drier

spring and summer in the second year. In both years, all plots receiving fungicide had significantly ($P \leq 0.05$) less scab when compared with those without fungicide sprays (treatments 1 and 4) (Fig. 1). Scab severity in plots receiving ARM sprays of fungicide plus conventional sprays of insecticide (treatment 6) and in plots receiving combined ARM sprays of both fungicide and insecticide (treatment 7) was not significantly different from that in plots receiving conventional sprays of fungicide, regardless of insecticide use (treatments 2, 3, and 5). Similar results were observed in the commercial orchards where scab severity in blocks with ARM sprays of fungicide was low and not significantly different from standard blocks receiving conventional fungicide sprays across years and cultivars (Fig. 2).

Fig. 1. Fruit scab severity in a study of pesticide treatment strategies against peach scab (caused by *Cladosporium carpophilum*) and plum curculio (*Conotrachelus nenuphar*) in a research peach orchard cv. Blake in A, 1999 and B, 2000. Conv. = spray applied conventionally to both sides of the trees; ARM = alternate-row middle spray with reduced tractor speed and unchanged application intervals relative to conventional spraying. Values are means and standard errors of four replicate plots with 120 fruit assessed per plot. Means with the same letters are not significantly different based on a multiple *t* test at $\alpha = 0.05$. Table 1 explains the treatment strategies and pesticide rates.

Fig. 2. Fruit scab severity and fruit damage incidence by plum curculio (PC) in a study of standard and alternate-row middle (ARM) pesticide application strategies against peach scab (caused by *Cladosporium carpophilum*) and plum curculio (*Conotrachelus nenuphar*) in large blocks in two commercial peach orchards. Values are means and standard errors of two cultivars (Sunprince and O'Henry) and 2 years (1999 and 2000) with 120 fruit assessed per block. Table 2 explains the treatment strategies and pesticide rates.

Trtmt.	1	2	3	4	5	6	7
Fung.	—	Conv.	Conv.	—	Conv.	ARM	ARM
Insect.	—	Conv.	—	Conv.	ARM	Conv.	ARM

Fig. 3. Fruit damage incidence by plum curculio (PC) in a study of pesticide treatment strategies against peach scab (caused by *Cladosporium carpophilum*) and plum curculio (*Conotrachelus nenuphar*) in a research peach orchard cv. Blake in **A**, 1999 and **B**, 2000. Conv. = spray applied conventionally to both sides of the trees; ARM = alternate-row middle spray with reduced tractor speed and unchanged application intervals relative to conventional spraying. Values are means and standard errors of four replicate plots with 120 fruit assessed per plot. Means with the same letters are not significantly different based on a multiple *t* test at $\alpha = 0.05$. Table 1 explains the treatment strategies and pesticide rates.

Plum curculio damage. Lower damage incidence by plum curculio was apparent in 2000 compared with 1999, likely a consequence of rainy weather in 1999 resulting in washoff or weathering of insecticide residues. In the research orchard in 1999, treatments without insecticide use (treatments 1 and 3) resulted in the greatest damage incidence by plum curculio (Fig. 3A). Incidence in plots receiving combined ARM sprays of fungicide and insecticide (treatment 7) was not significantly different from that in plots receiving conventional sprays of insecticide only (treatment 4), ARM sprays of insecticide plus conventional sprays of fungicide (treatment 5), or conventional sprays of insecticide plus ARM sprays of fungicide (treatment 6). Plots receiving conventional sprays of fungicide and insecticide (treatment 2) did not demonstrate expected levels of plum curculio control; indeed, damage incidence in this treatment was not significantly different from the untreated control (Fig. 3A). This anomaly may have been due to the physical location of the corresponding plots in the experiment, with all four plots receiving conventional sprays of both pesticides being by chance located adjacent to plots or trees receiving no insecticides, including unsprayed controls or unused spare trees. These trees may have provided a source for insect immigration, thereby reducing the efficacy of insecticide applications in adjacent plots.

In 2000, no difference in damage incidence was observed among plots receiving ARM sprays of insecticide (treatments 5 and 7) and those receiving conventional sprays of insecticide (treatments 2, 4, and 6) regardless of fungicide use (Fig. 3B). In the commercial orchards, there was no difference in damage incidence between blocks with ARM sprays of insecticide and those receiving conventional sprays of insecticide across years and cultivars (Fig. 2).

Fruit quality. In the research orchard in 1999, untreated control plots (treatment 1) and plots receiving conventional sprays of insecticide without fungicide sprays (treatment 4) had very poor fruit quality, with only 4.6 and 1.4% of fruit graded as Fancy, respectively (Fig. 4A). Plots with conventional sprays of fungicide without insecticide sprays (treatment 3) produced a greater proportion of Fancy fruit, but some fruit contained larvae of the plum curculio, rendering all fruit from these plots unmarketable. Combined ARM sprays of fungicide and insecticide (treatment 7) produced fruit quality as good as conventional sprays of both pesticides (treatment 2), with most fruit graded as Fancy. Good fruit quality also was observed in plots with ARM sprays of insecticide or fungicide plus conventional sprays of the other pesticide (treatments 5 and 6).

Trends in fruit quality among treatments were similar in the research orchard in

2000. Plots with sprays of both pesticides, either both conventional, both ARM, or one conventional plus the other ARM, produced high levels of fruit quality, with almost all fruit classified as Fancy (Fig. 4B). By comparison, other treatments either led to poor overall quality (treatments 1 and 4) or Wormy fruit (treatment 3). In the commercial orchards across the 2 years, conventional and ARM sprays resulted in similar and excellent fruit quality, with >99% of fruit in the Fancy grade (data not shown).

Environmental and economic impacts.

In the research orchard, EIQ values in plots with ARM sprays of fungicide and/or insecticide (treatments 5, 6, and 7) were reduced compared with plots receiving conventional sprays of both pesticides (treatment 2) (Table 3). Combined ARM sprays of both pesticides (treatment 7) produced the lowest EIQ values, with reductions relative to the treatment having conventional sprays of both pesticides of 6.2 and 21.1% in 1999 and 2000, respectively (Table 3). The greater reduction in 2000 was due to the more frequent use of sulfur relative to captan in that year; sulfur has a higher EIQ score compared with captan, primarily due to its high application rate and its detrimental effect on certain beneficial arthropods (18). In the commercial orchards, combined ARM sprays of pesticides reduced EIQ values by 12.5 to 14.8% compared with the standard (Table 4).

Evaluation of spraying time indicated that every combined ARM spray saved 33% spraying time in the research orchard (one-half of the rows sprayed at three-quarters of the conventional speed) and 25% in the commercial orchards (one-half of the rows sprayed at two-thirds of the conventional speed). During the spray period from petal fall to the preharvest interval, spraying time was reduced by 16.7 to 18.5% in the research orchard (data not shown) and by 12.5 to 15.6% in the commercial orchards (Table 4).

Overwintered inoculum. In the research orchard, conidial production potential was significantly greater on twigs receiving no fungicide than on twigs receiving fungicide the previous year (Fig. 5). Twigs with ARM sprays of fungicide (treatments 6 and 7) had levels of conidia that were not significantly different from those twigs with conventional sprays of fungicide (treatments 2, 3, and 5). In the commercial 'Sunprince' orchard, conidial production potential similarly was not significantly different between twigs with conventional and ARM sprays of fungicide (Fig. 6). No conidia were obtained from twigs in the 'O'Henry' orchard, presumably because fungicides were applied for controlling blossom blight before twigs were sampled.

Fig. 4. Fruit quality in a study of pesticide treatment strategies against peach scab (caused by *Cladosporium carpophilum*) and plum curculio (*Conotrachelus nenuphar*) in a research peach orchard cv. Blake in **A**, 1999 and **B**, 2000. Conv. = spray applied conventionally to both sides of the trees; ARM = alternate-row middle spray with reduced tractor speed and unchanged application intervals relative to conventional spraying. Open, hatched, gray, and black columns indicate fruit grades of "Fancy", "U.S. No.1", "U.S. No.2" and "Wormy" (with larvae of *Conotrachelus nenuphar*), respectively. Table 1 explains the treatment strategies and pesticide rates.

Table 3. Potential nontarget pesticide effects associated with peach scab and plum curculio treatment strategies in a research peach orchard cv. Blake in 1999 and 2000^a

Treatment strategy ^b	1999		2000	
	EIQ	Reduction in EIQ ^c (%)	EIQ	Reduction in EIQ (%)
2	2816.6		2796.2	
3	2600.0	7.7	2528.5	9.6
4	216.6	92.3	267.7	90.4
5	2777.7	1.4	2751.6	1.6
6	2680.1	4.8	2250.2	19.9
7	2641.5	6.2	2205.6	21.1

^a Potential nontarget effects were expressed with the Environmental Impact Quotient (EIQ) as described by Kovach et al. (18).

^b Table 1 explains the fungicide and insecticide schedules and rates.

^c Relative to treatment 2 (standard).

Table 4. Reductions in potential nontarget pesticide effects and in pesticide application time associated with use of midseason alternate-row middle (ARM) spraying against peach scab and plum curculio in two commercial peach orchards in 1999 and 2000^a

Cultivar and year	Treatment strategy ^b	EIQ	Reduction in EIQ ^c (%)	Reduction in application time (%)	
				Single spray	Season-long ^d
Sunprince 1999	Standard	3016.2			
	ARM ^e	2585.9	14.3	25.0	14.3
2000	Standard	3543.7			
	ARM	3100.7	12.5	25.0	12.5
O'Henry 1999	Standard	3049.6			
	ARM	2611.0	14.4	25.0	15.6
2000	Standard	2248.3			
	ARM	1916.1	14.8	25.0	12.5

^a Potential nontarget effects were expressed with the Environmental Impact Quotient (EIQ) as described by Kovach et al. (18).

^b Table 2 explains the fungicide and insecticide schedules and rates.

^c Relative to the standard.

^d Includes pesticide applications from petal fall to the preharvest interval.

^e ARM = alternate-row middle spray strategy. Sprays were applied at reduced tractor speed, but application intervals remained unchanged relative to conventional spraying.

Fig. 5. Density of overwintered scab inoculum early in the following season in a study of pesticide treatment strategies against peach scab (caused by *Cladosporium carpophilum*) and plum curculio (*Conotrachelus nenuphar*) in a research peach orchard cv. Blake in **A**, 1999 and **B**, 2000. Conv. = spray applied conventionally to both sides of the trees; ARM = alternate-row middle spray with reduced tractor speed and unchanged application intervals relative to conventional spraying. Values are means and standard errors of four replicate plots with ten twigs assessed per plot. Means with the same letter are not significantly different based on a multiple *t* test at $\alpha = 0.05$. Table 1 explains the treatment strategies and pesticide rates.

DISCUSSION

Combined spraying of fungicide and insecticide during midseason using an ARM approach with reduced operation speed and unchanged application intervals relative to conventional spraying resulted in levels of scab and plum curculio damage not significantly different from the commercial standard. Plots receiving ARM fungicide sprays plus conventional insecticide applications or vice versa also demonstrated low levels of the two pests consistent with results obtained previously (16,26). Not surprisingly, treatments in which either fungicides or insecticides were omitted entirely resulted in poor control.

Differences in fruit quality between treatment strategies generally reflected differences in efficacy of the spray treatments against the two pests. Similar to the standard with conventional sprays of both pesticides, low levels of scab severity and insect damage incidence translated into high levels of fruit quality in the combined ARM sprays and the ARM sprays of one of the pesticides plus conventional sprays of the other pesticide. By contrast, conventional sprays of only one of the pesticides with the other omitted produced either Wormy or low-quality fruit depending on whether the insecticide or fungicide was omitted. It is interesting to note that levels of pest injury did not always directly correlate with fruit quality. For example, the low levels of both scab severity (0.01%) and damage incidence by plum curculio (3.75%) in the plots receiving conventional sprays of fungicide without insecticide in 2000 resulted in >99% of fruit graded as Fancy; nevertheless, if this had been a commercial fruit load, all fruit would have been unmarketable because of the presence of some fruit with internal larvae or larval tunnels.

ARM spraying as implemented in this study results in reduced pesticide inputs and, as such, could lead to the buildup of pest pressures in subsequent growing seasons. For scab, overwintered inoculum potential measured on 1-year-old twigs from the research and commercial orchards showed that ARM sprays of fungicides did not lead to increased production of primary inoculum in the following year. This is consistent with results reported previously by Scherm and Savelle (26). These authors further documented that ARM sprays, applied at reduced tractor speed as in the present study, produced fungicide coverage similar to conventional spraying; this explains the effective suppression of fruit and twig scab observed here.

Use of reduced-input fungicide programs for peach scab control has been reviewed recently (26). For controlling plum curculio, reduced-input insecticide programs have also been investigated previously with different approaches. However, most of these studies were carried out on apple in the northeastern United States

or in Canada, where only one generation of the insect occurs per year (4,23,25,29). These previous efforts therefore focused on reduced-input application strategies against overwintered plum curculios migrating into the orchard in early spring, e.g., by spraying only the peripheral zone of the orchard at petal fall. This strategy resulted in very low levels of fruit damage and reduced insecticide use by 70 to 75% (5,28). In peach in the southeastern United States, where two generations of the insect occur, an insecticide schedule with season-long ARM sprays (nine applications) resulted in control of plum curculio equivalent to a schedule with season-long conventional sprays (20). This approach of season-long ARM spraying differs from that used in our study in which ARM spraying was limited to periods with reduced plum curculio pressure. Due to the high quality demands on peach fruit destined for the wholesale fresh-market, ARM spraying would be inadvisable for plum curculio control during the high-pressure period from petal fall through first cover.

In most integrated pest management (IPM) programs, pesticides are selected on the basis of their efficacy and/or cost. With increased awareness of potential nontarget effects, however, increased attention has been devoted to reducing potential environmental and health hazards associated with pesticide use. Use of the EIQ has been proposed as a convenient index to compare environmental effects of different pesticides and/or pest management programs (7-9). In the present study, combined ARM spraying of fungicide and insecticide reduced the total EIQ by as much as 21.1% compared with the com-

mercial standard. Greater reductions were not achieved because conventional pesticide applications were still used during the high-risk early-season period. It may be possible to combine the midseason ARM approach described here with a tree phenology-based reduced pesticide program during the early season (12), thereby further reducing pesticide use and potential nontarget effects.

In addition to satisfactory pest control, excellent fruit quality, and reduced nontarget effects, the combined ARM spray strategy also reduced spraying time compared with conventional sprays. This implies savings in labor costs and for procurement and operation of agricultural equipment such as sprayers. Additional savings may be possible with predictive models for *C. carpophilum* and *Conotrachelus nenuphar*. Such models are currently under development for use in southeastern peaches (Z. Lan, H. Scherm, and D. L. Horton, unpublished).

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Fig. 6. Density of overwintered scab inoculum early in the following season in a study of standard and alternate-row middle (ARM) pesticide application strategies against peach scab (caused by *Cladosporium carpophilum*) and plum curculio (*Conotrachelus nenuphar*) in large blocks in a commercial peach orchard cv. Sunprince in 1999 and 2000. Values are means and standard errors of four (1999) or three (2000) replicates with 10 twigs assessed per replicate. Means with the same letter are not significantly different based on a *t* test at $\alpha = 0.05$. Table 2 explains the treatment strategies and pesticide rates.

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