DEVELOPMENT OF A PEST MANAGEMENT PROGRAM FOR THE CONTROL OF LEAFHOPPER VECTORS OF *XYLELLA FASTIDIOSA* IN NORTH CAROLINA VINEYARDS

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ABSTRACT
Three insecticide programs were evaluated in two vineyards in North Carolina from 2006 to 2008 for managing leafhopper vectors of *Xylella fastidiosa* (*Xf*), the bacterium that causes Pierce's disease in grapes. In 2006, the treatments consisted of applications of Assail®, Danitol®, Provado®, or Venom®, in different sequences and frequencies during the growing season. The same insecticides were used in 2007, except Provado®, whereas Admire-Pro®, Belay® and all insecticides used in 2007 were used in 2008. Most insecticides were applied as a foliar spray except Venom which was applied to the foliage and soil and Admire-Pro and Belay which were only applied to the soil. Soil applications were made along the base of the vines. Leafhoppers were monitored in each plot with yellow sticky traps which were changed every two weeks. *Graphocephala versuta* was the most abundant and ubiquitous leafhopper that was trapped in the test plots. Five other species of sharpshooters were identified: *Cuerna costalis, Paraulacizes irrorata, Oncometopia orbona, Homalodisca insolita,* and *H. vitripennis.* However, the latter was only detected in 2007 and 2008. All insecticide treatments significantly reduced the number of leafhoppers trapped compared with the control during the three seasons.

INTRODUCTION
Several species of leafhopper vectors of *Xylella fastidiosa* (*Xf*), the causal agent of Pierce's disease (PD), are abundant in vinifera vineyards in North Carolina (Myers et al. 2007). PD severely affects *vinifera* grapes debilitating the plants, reducing the productivity life span of vines and increasing costs in vineyards (Purcell and Hopkins 1996). This disease is a limiting factor for the development of the vinifera industry in North Carolina and has been detected in many of the grape growing regions in the eastern two-thirds of the state (Anas et al. 2008). In this paper we report preliminary results of insecticide tests for managing leafhoppers conducted between 2006 and 2008. These tests were conducted in two vineyards located in Wake and Alamance counties. Insecticide classes and rates used are presented in **Table 1**. In 2006, the treatments consisted of single applications of Assail®, Danitol®, Provado®, or Venom®, in different sequences and frequencies during the growing season (**Table 2a**). All insecticides used in 2006 were used in 2007, except Provado® (**Table 2b**), whereas Admire-Pro®, Belay® and all insecticides used in 2007 were used in 2008 (**Table 2c**). Venom was applied to the foliage and soil, whereas Admire-Pro, and Belay were only used as soil applications, and the remainder of insecticides were applied to the foliage. Leafhoppers were monitored with yellow sticky traps placed in the middle row of each plot and replaced every two weeks. All vines in the middle rows of each plot were tested for the presence of *Xf* using an ELISA test kit (Agdia Inc., Elkhart, IN).

OBJECTIVES
1. To evaluate the effectiveness of insecticide programs on populations of leafhoppers in vineyards of North Carolina.
2. Develop an IPM program for leafhoppers for vinifera vineyards in North Carolina.

RESULTS AND DISCUSSION
During peak population periods, and throughout most of the growing season, fewer leafhoppers were found in the insecticide treatments than the control in 2006, 2007, and 2008, (**Figures 1 and 2**). *Graphocephala versuta* was the most abundant and ubiquitous leafhopper trapped during the three growing seasons. Significantly more *G. versuta* ($P < 0.05$) were found in the control compared to all the insecticide treatments in 2006, 2007, and 2008 (**Figures 1a, 1b, 1c, and 3a**). A similar trend was observed for all sharpshooters though there was no significant difference among treatments in 2008 (**Figures 2a, 2b, 2c, and 3b**). Five species of sharpshooters were found in the traps: *Cuerna costalis*, *Homalodisca insolita*, *H. vitripennis*, *Oncometopia orbona*, and *Paraulacizes irrorata*. The most abundant were *H. insolita* and *O. orbona*. The glassy-winged sharpshooter *H. vitripennis* was only found in 2007 and 2008 in the Wake Co. vineyard. The peak population of *O. orbona* occurred from mid-June to the first week of July whereas, *H. vitripennis* peaked between mid-July and mid-August. Peak numbers of *G. versuta* were delayed by ~3 weeks in 2007 compared with 2006 (**Figures 1a and 1b**) which may be due to a hard freeze from 6 to 10 April 2007. Similarly, a severe late freeze between 13 and 16 April 2008 may have decreased leafhopper numbers in 2008 compared to the two previous years (**Figures 1, 2 and 3**). These two freeze events may also have affected the survival of *Xf* because the incidence PD in the Alamance Co. vineyard was reduced in 2007 and 2008 (**Table 3**). The Wake Co. grower removed the vines in August 2008 and no PD evaluation was possible. There were no significant treatment effects on PD incidence as measured by ELISA.

Table 1. Insecticide classes and rates.

Type	Insecticide (Trade name)	Rate/Ha	
Neonicotinoid	acetamiprid (Assail 30 SG)	77.0	g
"	imidacloprid (Provado 1.6 F*)	274.1	ml
"	(Admire Pro▲♦)	1024.8	ml
"	dinotefuran (Venom insecticide)	210.0	g
	(Venom insecticide♦)	420.1	g
	clothianidin (Belay▲♦)	878.4	ml
Pyrethroid	fenpropathrin (Danitol 2.4 EC)	1460.5	ml

(*) Provado was used only in 2006 and (▲) Admire Pro and Belay were used only in 2008. (♦) Indicates soil application. In all other cases insecticides were applied to the foliage, unless indicated.

Table 2. Insecticide application schedule for (a) 2006, (b) 2007, and (c) 2008.

(a) 2006

Treat.	15-Apr	3-May	17-May	1-Jun	15-Jun
T1	Danitol	Assail	Danitol	Assail	Venom
T2	Danitol	Provado	Danitol	Provado	Venom
T3	Venom♦	-	Venom	Danitol	Assail
Control	-	-	-	-	-

(b) 2007

Treat.	27-Mar	12-Apr	26-Apr	9-May	23-May	5-Jun	19-Jun	3-Jul	17-Jul
T1	Venom♦	-	Venom	Danitol	Assail	Danitol	Assail	-	-
T2	-	Venom♦	-	Venom	Danitol	Assail	Danitol	Assail	-
T3	-	Venom♦	-	Venom	Danitol	-	Assail	Danitol	Assail
Control	-	-	-	-	-	-	-	-	-

(c) 2008

Treat.	2-Apr	15-Apr	29-Apr	12-May	27-May	10-Jun	24-Jun	8-Jul	22-Jul
T1	Venom♦	-	Venom	Danitol	Assail	Danitol	Assail	-	-
T2	-	Venom♦	-	Venom	Danitol	Assail	Danitol	Assail	-
T3	-	Venom♦	-	AdmirePro♦		Belay♦	-	Danitol	Danitol
Control	-	-	-	-	-	-	-	-	-

Table 3. Percentages of PD in middle row plants (Wake: n=96, Alamance: n=142). The grower removed all plants in the Wake Co. vineyard in 2008. The Alamance Co. grower replaced vines killed by PD in the spring of 2008. If these vines are considered, the percentage vines affected would be 13.1% for 2008.

Year	County Location	
	Wake*	Alamance
2006	24.5%	73.1%
2007	72.2%	11.8%
2008*	n/a	4.2%

Figure 1. Effect of insecticide treatments on *G. versuta* populations: (a) 2006, & (b) 2007. Treatments with same designation differed between years. See Table 2.

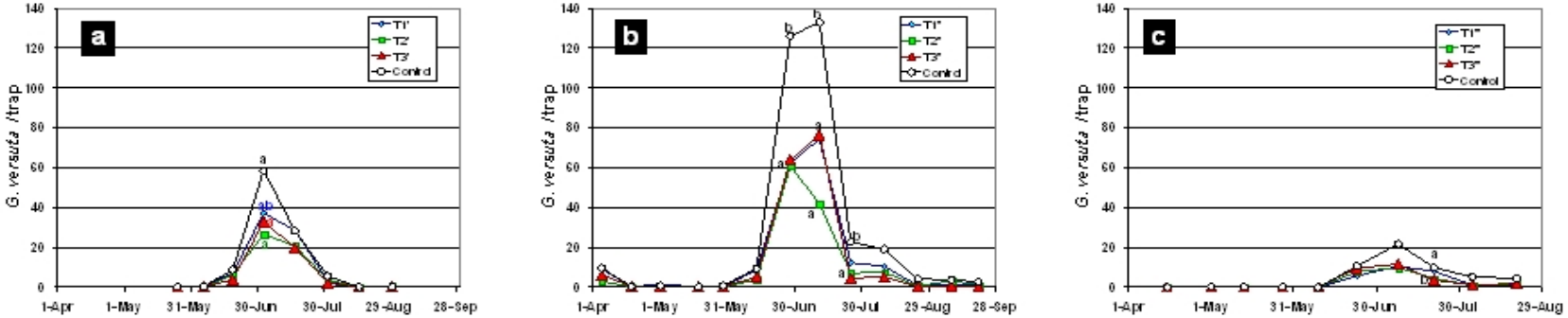


Figure 2. Mean No. of sharpshooters/trap in insecticide treated and control plots in (a) 2006, and (b) 2007. See Table 2

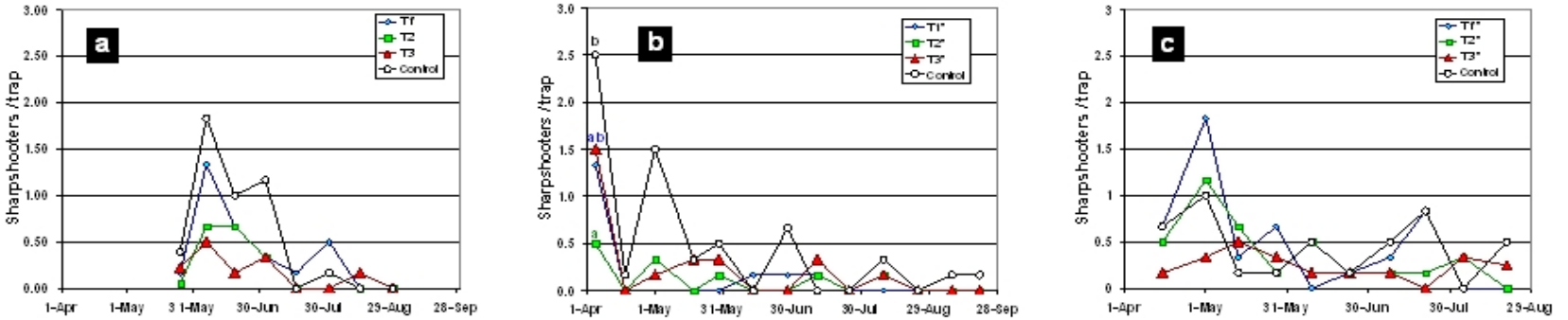
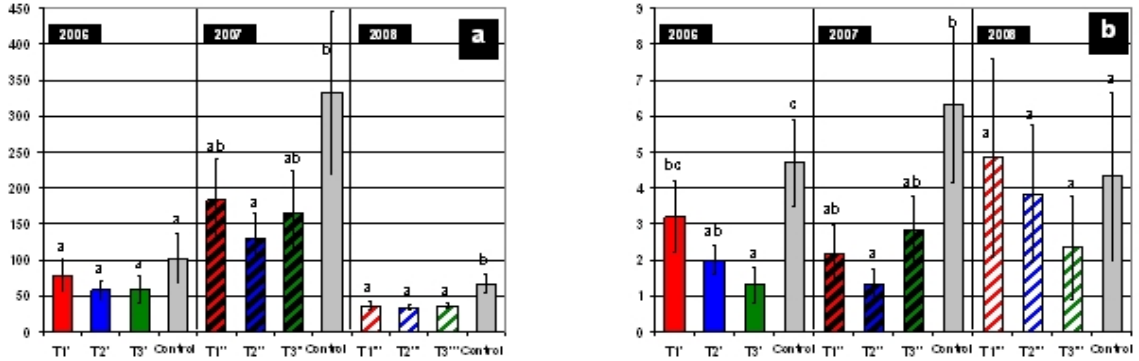


Figure 3. Mean total (±SEM) (a) *G. versuta* and (b) sharpshooters per 8 traps in 2006 (15-May to 30-Aug.), per 13 traps in 2007 (22-Mar to 20-Sep.), and per 10 traps in 2008 (Mean separation within year; P≤0.05. See Table 2).



CONCLUSIONS

All the insecticide management programs we studied reduced the numbers of total sharpshooters and *G. versuta* in the treated plots compared with the control. In addition, in most cases, the insecticide treatments also reduced the numbers of other leafhopper species (data not shown) during the three-year study. *Graphocephala coccinea*, *Ponana puncticollis*, *Paraphlepsius irroratus*, *Texananus scultus, Norvellina seminude*, *Gyponana*, *Draecucephala* sp., *Scaphoideus titanus*, *Scaphytopius*, and *Agalliota* sp. were some of the species collected in this study and may be potential vectors *Xf*. Some of these species had been reported as carriers of *Xf* (Purcell 1979, Myers et al. 2007) but have not been shown to transmit *Xf*. Based on our tests, North Carolina vinifera grape growers have several options that will suppress populations of leafhoppers. However, the program still needs to be refined to be more cost effective. Additionally, the effect of these programs on reducing vines infected with *Xf* needs further evaluation. Although we did not see any differences in the incidence of PD between treated and non-treated vines in our small test plots, we have some evidence from a vineyard trial that insecticide applications will reduce the incidence of PD. In 2008, we initiated a test in a newly planted vineyard to assess the effectiveness of one of our programs (T3, 2008) compared to the grower's program. When our program was used in a vineyard planted in 2008 (n=592), PD symptoms were observed in only 4.4% of vines in late September whereas in an adjacent vineyard with replanted vines (n=74) where our program was not used, 44 plants (59.4%) had PD symptoms. Only one vine in each plot tested positive for *Xf* using ELISA. Visible symptoms (marginal leaf scorch) occurred late in the season consequently the titer of *Xf* may have been too low to detect using ELISA. This test will be continued to evaluate the long-term effectiveness of the program.

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Section 3: Pathogen Biology and Ecology