Field Experiments for Evaluation of Insects and Diseases in a Double-Cropped Corn System for Virginia

Introduction

In southwestern Virginia, late-planted corn for silage is more common than late-planted corn for grain. A short growing season will limit the number of planting options in the Shenandoah Valley and mountainous portions of western Virginia. The following experiments were carried out in Blacksburg, VA and at the Kentland Farm in Whitethorne, VA and are more applicable to corn grown for silage in western Virginia rather than to corn grown for grain in eastern Virginia.

Materials and Methods

Factorial experiments were conducted at Whitethorne and Blacksburg locations in Montgomery County, Virginia from 1998 to 2000 in order to evaluate the potential constraints on double-cropped corn following the harvest of barley by insects and pathogens. In all experiments, corn was planted at a density of 27,027 seeds/acre (66,785 seeds/ha) into barley stubble using no-tillage methods.

Independent variables in the experiments and factorial treatment arrangements are shown in Table 1. Treatments were arranged in a randomized complete block design with four replications. Individual plots consisted of 4 rows where the center 2 rows were harvested for yield. Field experiments were conducted using a 2x2x3 factorial design with two near-isoline hybrids (NK4640 and NK4640Bt), insecticides at planting (tefluthrin in all years, 1998-2000; and imidacloprid in 1999 and 2000), and fungicide treatments (azoxystrobin or propiconazole). Response variables included yield, moisture at harvest, grain test weight, damage by European corn borer (*Ostrinia nubilalis*), damage by corn earworm (*Heliothis zea*), disease progress curves for gray leaf spot (*Cercospora zeae-maydis*), and number of plants exhibiting virus symptoms. Plots receiving applications of 5.5 oz product/1000 feet of row of Force 3G (tefluthrin) in-furrow were compared to non-treated plots to estimate the impact of seed-feeding insects. Foliar fungicide treatments were used as a disease free comparison to the no-fungicide treatments. The fungicides used were Tilt 3.6EC (propiconazole) at 4.0 fl. oz. product/A or Quadris (azoxystrobin) at 8.0 fl. oz. product/A. Stand counts were taken following emergence of the crop, approximately two weeks after planting.

At tasseling and after the completion of vegetative growth, plant height was recorded for 10 plants per plot in 1998 and 1999. On approximately October 1 damage by European corn borer and corn earworm was rated for a total of 10 plants in each plot. Five consecutive plants in each of the outer rows were examined visually and stalks were split open using a knife if a stalk tunnel was detected. For European corn borer, the number of leaves damaged, number of egg masses, number and length of stalk tunnels, number of ear tunnels, number of shank tunnels, number of pupae, and number of larvae were recorded. The number of corn earworms found in ears was recorded. For gray leaf spot, the percentage leaf area diseased was visually estimated for each plot at 40, 57, 87, 103, and 188 days after planting at the Whitethorne location based on a standard assessment diagram (Ward, 1996). Area under the disease progress curve (AUDPC) was calculated for gray leaf spot using the midpoint method (Campbell and Madden, 1990). Corn yields were obtained by hand harvesting and were adjusted to 15.5% moisture.

Percent moisture and test weight was determined for each plot immediately following harvest. All data were subjected to analysis of variance using SAS software (SAS Institute, Cary, NC). Mean separation for fungicide treatments was based on Tukey's W procedure at a significance level of $\alpha = 0.05$.

Table 1. Summary of dates and locations for field experiments.

Year	**Location**	**Full season or double-cropped**	**Planting date**
1998	Whitethorne, VA	DC	June 22
1998	Blacksburg, VA	DC	June 24
1999	Whitethorne, VA	FS	May 17
1999	Whitethorne, VA	DC	June 14
2000	Whitethorne, VA	FS	May 12
2000	Whitethorne, VA	DC	June 16

1998

2 x 2 x 3 factorial

A: 1 N4640
2 N4640Bt

B: 1 No Insecticide
2 Insecticide: Tefluthrin (Force)

C: 1 No fungicide
2 Propiconazole (Tilt)
3 Azoxystrobin (Quadris)

1999 – 2000

2 x 2 x 3 factorial

A: 1 N4640
2 N4640Bt

B: 1 No Insecticide
2 Insecticide: Tefluthrin (Force)
3 Insecticide: Imidacloprid (Gaucho)

C: 1 No fungicide
2 Azoxystrobin (Quadris)

1998 Experimental Plots

Corn was planted on June 22, 1998 and June 24, 1998 at the Whitethorne and Blacksburg locations, respectively. At the Blacksburg location, 1qt/A of Round Ultra and 2.4 qt/A of Bicep II were applied preemergence. At the Whitethorne location, weeds were controlled by hand.

The Bt hybrid and its non-Bt near-isoline counterpart were used to estimate the impact of insect damage by European corn borer and corn earworm in years of significant insect pressure (1998).

Results and Discussion

1998 Double-cropped corn experiment at Blacksburg

At the Blacksburg location, the Bt hybrid performed significantly better than the non-Bt near isoline in height ($p<0.0001$), number of leaves damaged by ECB ($p<0.0001$), number of ECB stalk tunnels ($p<0.0001$), number of ECB larvae ($p<0.0001$), number of CEW damaged ears ($p<0.0013$), yield ($p<0.0071$), and test weight ($p<0.0484$), whereas the moisture at harvest was lower for the non-Bt hybrid ($p<0.0025$) (Tables 2 and 3). The effects of soil insecticide and foliar fungicide were not significant. No significant interactions were detected for any dependent variable at the Blacksburg location.

1998 Double-cropped corn experiment at Whitethorne

At the Whitethorne location, yields were not obtained for double-cropped corn due to a farm crew error of a premature harvest of the experimental plots. Measurements of average plant height, insects, and diseases were statistically significant, though no statistical analysis can be performed on yields. The Bt hybrid performed significantly better than the non-Bt near isoline in height ($p<0.0001$), number of leaves damaged by ECB ($p<0.0001$), number of ECB stalk tunnels ($p<0.0001$), number of ECB larvae ($p<0.0001$), and number of CEW damaged ears ($p<0.0122$) (Table 4). The AUDPC for gray leaf spot was significantly lower for the Bt hybrid than the non-Bt near isoline ($p<0.0157$). There are several possible explanations for the effect of hybrid on AUDPC. These include a direct effect of the Bt gene on the pathogen, a bias in rating insect damaged leaves which appear tattered and have a smaller leaf area than a healthy leaf, a reduction in host vigor due to insect damage resulting in greater disease development, or genetic differences between these near isolines hybrids in susceptibility to gray leaf spot. The effects of soil insecticide were not significant. The effects of foliar fungicide were significant for the AUDPC for gray leaf spot.

Approximately 60% of the plants in this field had symptoms typical of maize dwarf mosaic caused by maize dwarf mosaic virus including mottling and light green streaks along the leaf veins. The Whitethorne location contained natural infestations of rhizomatous johnsongrass, the primary overwintering reservoir host of the virus. A nearby field of no-tillage continuous corn with a disease history of gray leaf spot (*Cercospora zeae-maydis*) was a likely source of inoculum for gray leaf spot in this experiment.

Table 2. Summary of agronomic measurements at the Blacksburg location in 1998.

Hybrid	Height (cm)	Yield (Bu/ac)	% Moisture at Harvest	Test weight (lb/bu)
N4640	213.6	72.1	21.9	49.0
N4640Bt	232.2	88.6	24.4	49.8
p-value	<0.0001	<0.0071	0. 0025	0.0484

Table 3. Summary of insect ratings (per stalk) at the Blacksburg location in 1998.

Hybrid	Damaged leaves	ECB tunnels	ECB larvae	CEW damaged ears
N4640	2.59	1.32	0.45	0.95
N4640Bt	0.49	0.03	0.01	0.57
p-value	<0.0001	<0.0001	<0.0001	<0.0013

Table 4. Summary of insect ratings (per stalk) at the Whitethorne location in 1998.

Hybrid	Damaged leaves	ECB tunnels	ECB larvae	CEW damaged ears
N4640	3.91	0.85	0.342	0.31
N4640Bt	0.34	0.03	0.004	0.16
p-value	<0.0001	<0.0001	<0.0001	0.0122

Figure 2. 1998 Double Cropped-corn – Whitethorne gray leaf spot (*Cercospora zeae-maydis*) disease progress curve.

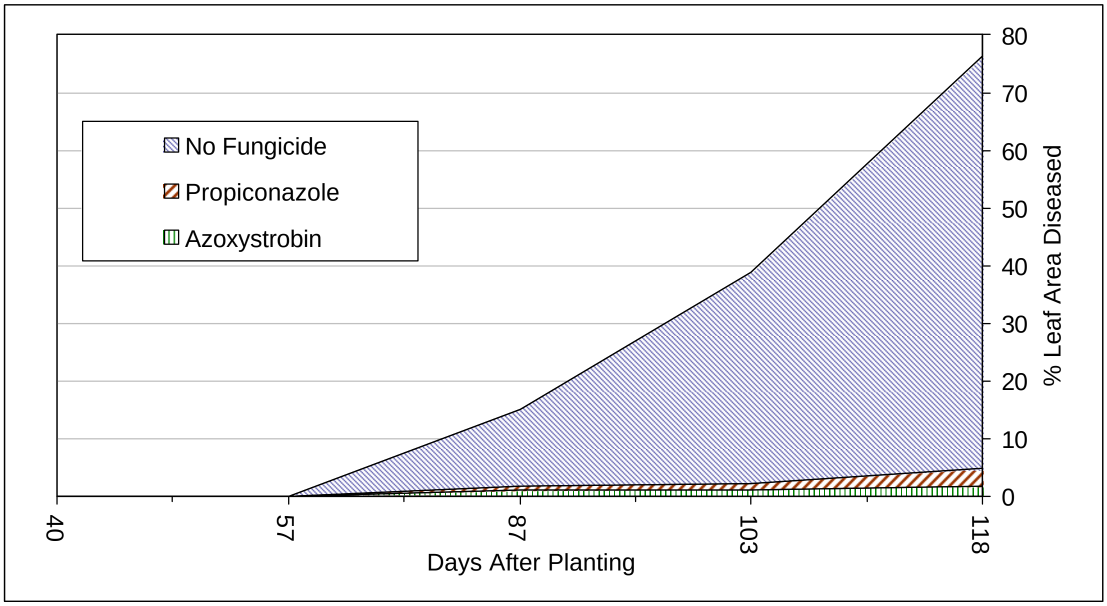
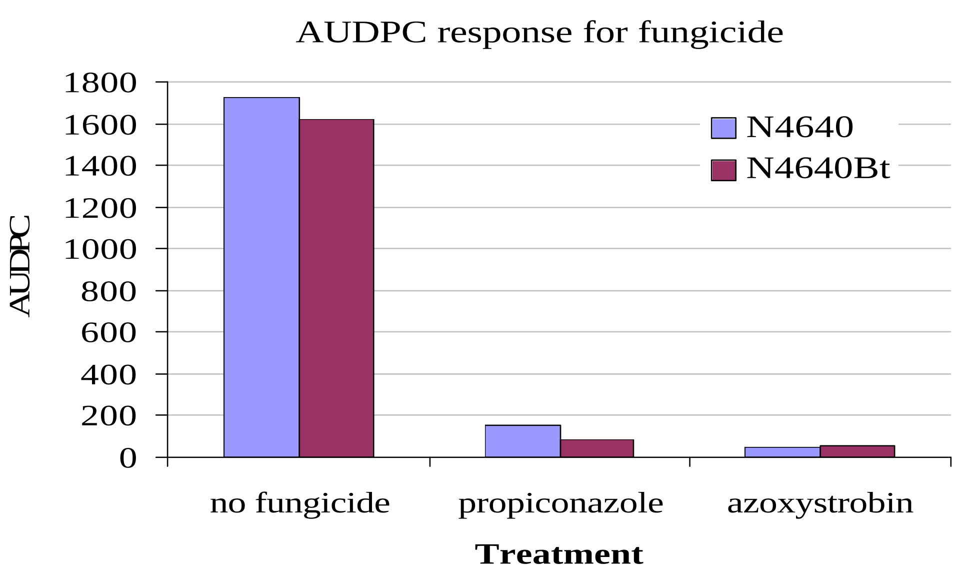


Figure 3. Area under the disease progress curve (AUDPC) response for fungicide in 1998.



1999 Full season corn experiment at Whitethorne

The Bt hybrid performed significantly better than the non-Bt near isoline in yield ($p<0.0061$), and test weight ($p<0.0374$), whereas the moisture at harvest was lower for the non-Bt hybrid ($p<0.0011$).

The fungicide treated plots had a higher yield ($p<0.0017$) and test weight ($p<0.0297$), and a lower moisture at harvest ($p<0.0001$) and AUDPC ($p<.0001$) compared to the plots receiving no fungicide.

A seed treatment of imidacloprid (Gaucho) showed no statistically significant differences at the 5% alpha level for all measurements. Gaucho treated plots yielded an average of 163.980 bu/acre and non-Gaucho treated plots averaged 157.938 bu/acre, a difference of 6.042 bu/acre. No significant interactions were detected for any dependent variable in this experiment.

Table 5. Summary of agronomic measurements for full season corn at the Whitethorne location in 1999.

Hybrid	**Yield (Bu/ac)**	**% Moisture at Harvest**	**Test weight (lb/bu)**
N4640	155.586	16.1563	51.7188
N4640Bt	166.331	16.9563	52.7250
p-value	0.0061	0. 0011	0.0374

Table 6. Summary of fungicide response for full season corn at the Whitethorne location in 1999.

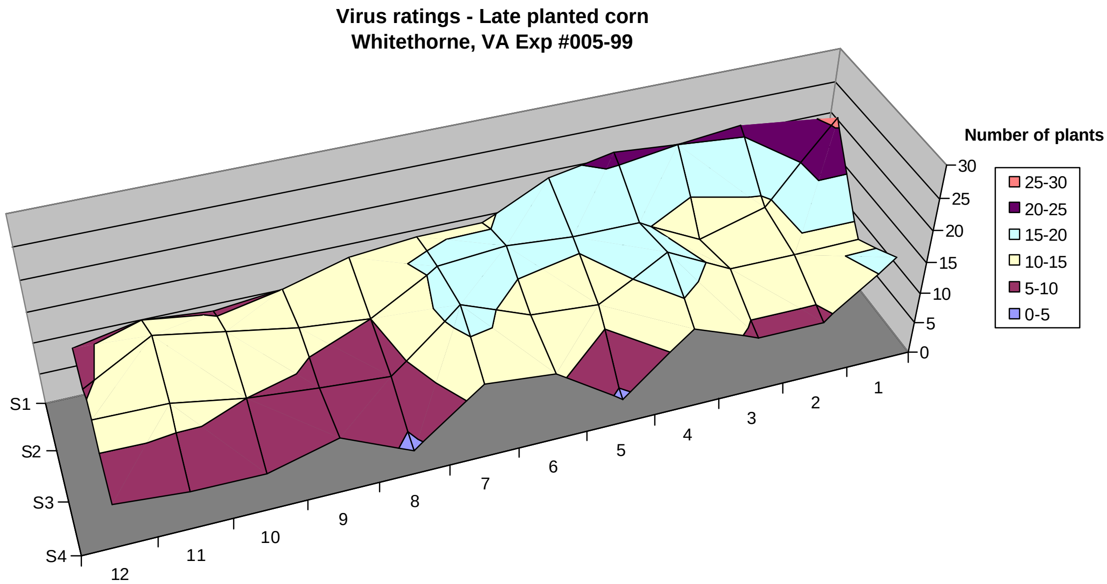
Foliar fungicide	**Yield (Bu/ac)**	**% Moisture at Harvest**	**Test weight (lb/bu)**	**AUDPC**
No fungicide	154.622	15.6688	52.7500	276.156
Quadris	167.296	17.4438	51.6938	108.625
p-value	0.0061	<0.0001	0.0374	<.0001

1999 Double-cropped corn at Whitethorne

There was no significant difference between hybrids in yield, moisture or test weights probably due to the poor yields obtained for the entire experiment. Yields of 65.348 bu/ac were obtained for NK4640 and 58.42 bu/ac for the NK4640Bt hybrid, a 10.6% difference, but non-significant. The only statistically significant difference for this entire experiment was found in the moisture at harvest where azoxystrobin treated plots had a higher moisture content at harvest ($p<0.0067$) than the non-treated plots. Treated plots had a mean of 14.7 percent moisture at harvest and non-treated averaged 14.0 percent moisture.

While the number of plants (n = 28) exhibiting symptoms of MDMV, MCDV or both were not statistically significant in the analysis of variance for the factorial design, a surface plot of the counts reveals a gradient of high counts in the NE corner to low numbers in the SW corner (Figure 4). This suggests that a local reservoir of vectors and virus may be present. This source of variation across the experiment may have contributed to the lack of statistically significant differences among treatments.

Figure 4. Surface plot of the number of plants exhibiting virus symptoms of MDM and MCD in each plot of the 1999 double-cropped corn experiment at Whitethorne.



2000 Full season corn experiment at Whitethorne

The Bt hybrid performed significantly better than the non-Bt near isoline in yield ($p<0.0002$), and test weight ($p<0.0001$), whereas the moisture at harvest was lower for the non-Bt hybrid ($p<0.0003$) (Table 7). The fungicide treated plots had a higher yield ($p<0.0001$) and test weight ($p<0.0001$), and a lower moisture at harvest ($p<0.0001$) and AUDPC ($p<.0001$) compared to the plots receiving no fungicide treatment (Table 8).

A seed treatment of imidacloprid (Gaucho) resulted in statistically significant differences at the 5% alpha level for yield ($p<0.0487$) (Table 9). Gaucho treated plots yielded an average of 135.978 bu/acre and non- treated plots averaged 127.489 bu/acre, a difference of 8.489 bu/acre. All other measurements were not statistically significant for mean separation, though Gaucho treated plots had the highest average values for yield, moisture at harvest, and test weight. No significant interactions were detected for any dependent variable in this experiment.

Table 7. Summary of agronomic measurements for full season corn at the Whitethorne location in 2000.

Hybrid	**Yield (Bu/ac)**	**% Moisture at Harvest**	**Test weight (lb/bu)**
N4640	126.735	10.9375	56.4292
N4640Bt	139.360	12.1833	57.9250
p-value	0.0002	0.0003	0.0001

Table 8. Summary of fungicide response for full season corn at the Whitethorne location in 2000.

Foliar fungicide	**Yield (Bu/ac)**	**% Moisture at Harvest**	**Test weight (lb/bu)**	**AUDPC**
No fungicide	119.055	10.8667	56.5917	11.2083
Quadris	147.040	12.2542	57.7625	6.8750
p-value	0.0001	<0.0001	0.0001	<.0001

Table 9. Summary of measured responses to insecticide treatments for full season corn at the Whitethorne location in 2000. Means with the same letter are not significantly different.

Seed treatment	**Yield (Bu/ac)**	**% Moisture at Harvest**	**Test weight (lb/bu)**	**AUDPC**
No treatment	127.489 B	11.1938 B	56.8063 B	8.8750 A
Force	135.676 A	11.4688 BA	57.3250 AB	9.3125 A
Gaucho	135.978 A	12.0188 A	57.4000 A	8.9375 A
LSD	7.6088	0.76	0.5523	1.124
p-value	0.0487	0.0951	0.0729	0.6957

2000 Double-cropped corn at Whitethorne

The Bt hybrid performed significantly better than the non-Bt near isoline in yield ($p<0.0001$) and test weight ($p<0.0001$). Moisture at harvest was not statistically significant at the alpha = 0.05 level. The fungicide and seed treatment responses were not statistically significant in the late planted corn experiment (Table 10). No significant interactions were detected for any dependent variable in this experiment. For insecticide treatments at planting, no responses were statistically significant. Differences between means of the seed treatments are shown in Table 11.

Table 10. Summary of fungicide response for double-cropped corn at the Whitethorne location in 2000.

Hybrid	Yield (Bu/ac)	% Moisture at Harvest	Test weight (lb/bu)
N4640	37.243	12.7292	50.8875
N4640Bt	50.379	12.9792	53.2042
p-value	0.0001	0.1016	0.0001

Table 11. Yield differences among insecticide treatments for double-cropped corn at the Whitethorne location in 2000. Values were not statistically significant at the 0.05 level, but numerical differences are apparent.

Comparison	Yield Difference Between Means	95% Confidence Limits	
Gaucho - Force	0.838	-4.931	6.607
Gaucho – No Trt	5.942	0.011	11.895
Force – Gaucho	-0.838	-6.607	4.931
Force – No Trt	5.104	-0.764	10.971
No Trt - Gaucho	-5.942	-11.895	0.011
No Trt - Force	-5.104	-10.971	0.764

Conclusions

Bt hybrids appear to yield better than non-Bt hybrids in late planted corn, provided that adequate rainfall is available during anthesis. In full season corn production, comparisons of Bt hybrids to non-Bt hybrids have shown mixed results. Under conditions of light insect and disease pressure, Bt hybrids typically yield less than non-Bt hybrids in eastern Virginia. Experiments in Montgomery County in 1999 and 2000 Full season Bt hybrid yield and test weight performed better than the non-Bt hybrid under light to moderate European corn borer pressure. This may be explained by several factors. First, Bt hybrids expend resources to produce the Bt toxin in its tissues and may result in a yield drag. Second, for early planted non-Bt corn, the endogenous resistance of young corn to first generation ECB, and the preference of second generation ECB for corn that is still in vegetative growth stages may be sufficient in most years to avoid heavy ECB pressure.

Virus diseases of corn, such as maize dwarf mosaic virus (MDMV) or maize chlorotic dwarf virus (MCDV) can be severe in late planted corn. The risk is greatest when local reservoirs exist, such as johnsongrass, insect vectors and virus.

In areas where corn is planted near a local source of grey leaf spot (Cercospora zeae-maydis) inoculum, the disease can be severe and potentially yield limiting. The fungal pathogen causing grey leaf spot of corn is not commonly a problem in Virginia. It is most likely to occur in reduced- or no-tillage situations or where continuous corn is produced since the pathogen overwinters on infested corn debris. Fungicides provide effective control of grey leaf spot.