WORKING TO IMPROVE BLACK SHANK CONTROL IN FLUE-CURED TOBACCO

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ABSTRACT:

Black shank is a concern for farmers growing tobacco on land infested with *Phytophthora nicotianae*. The first superior *Php* gene variety (NC-71) was introduced in 1995. The *Php* gene confers complete resistance to the wild type of *P. nicotianae* (race 0), whereas traditional FL-301 resistance confers only partial resistance. By 2004, black shank was increasing where the *Php* gene was used as the sole means of control. This was due to a new pathogen race, designated race 1, selected in apparently mixed race populations as race 0 was eliminated by the *Php* gene. Black shank losses increased sharply in 2013, confirming that *Php* resistance would no longer control black shank in Georgia. A series of trials was begun in 2013 to improve black shank control. A 2013 trial of varieties and breeding lines conducted in a black shank site showed disease incidence of >85% in popular varieties (K-326, NC-71, and NC-196). Twelve breeding lines containing WZ genetics derived from *Nicotiana rustica* developed <10% disease. Very heavy rain during and just after transplanting in 2014, resulted in the highest black shank losses in 20+ years. In several cases where losses were high, mefenoxam had been used. Sensitivity tests performed on 30 isolates of *P. nicotianae* from such fields found all to be sensitive to mefenoxam. Mefenoxam is known to be prone to leaching with heavy rain. Trials conducted in 2014 found the varieties used for black shank control (NC-196 and GF-318) had only moderate to low levels of FL-301 resistance, providing 36.3% and 21.6% control respectively compared to K-326, the standard of low FL-301 resistance. These same trials identified three varieties that showed relatively good control compared to K-326 (NC-925, 81.4%; CC-143, 70.0%; GL-395, 63.5%). Black shank losses continued high in 2015. Variety trials conducted in 2015 confirmed the 2014 results. Flupicolide, a new chemical control option, reportedly less prone to leaching than mefenoxam, was tested in 2015. Control with a layby application of flupicolide (140 grams/ha) versus mefenoxam (560 grams/ha) was equal ($p=0.05$). Varieties with superior FL-301 resistance coupled with less leaching prone chemical options should improve black shank control. Resistance based on WZ genes offers a tool for further variety improvement.

INTRODUCTION:

Black shank, described in Georgia about 1915 and widespread by 1959, has long been a source of concern for those farmers forced to grow tobacco on land infested with the pathogen, *Phytophthora nicotianae* (4). Introduction of metalaxyl in 1980 provided a tool that gave very good control when used as part of a program that included rotation (two or more years between tobacco crops) and resistant varieties. At this time the only resistance available was partial resistance from breeding lines carrying a FL-301 package. The resistance from FL-301 appears to be based on multiple genes inherited in random combinations so that sister lines from the same cross can have very different levels of black shank resistance. This was illustrated by sister lines K-326 and K-346 in our 2016 variety trials (Table 1). Resistance from FL-301 operates by slowing disease development after infection rather than by reducing infection rate. The root system rots away more slowly with a high FL-301 resistance variety, allowing more plants to survive through harvest, than with a low FL-301 resistance variety. This unfortunately also means that when infection rate is high soon after transplanting losses can be very high even where the highest level of FL-301 resistance is deployed.

A source of resistance (the *Php* gene) was identified in *Nicotiana plumbaginifolia*. The *Php* gene provides total resistance to the wild type (race 0) of *P. nicotianae*. Variety development using this resistance began in the 1960's (4). As early 1967 a race of *P. nicotianae* was found to attack lines having the *N. plumbaginifolia* genes (1). The first the first high quality variety with the *Php* gene (Cooker-371 gold) was introduced in 1986. This variety never became popular and was never widely planted due to several undesirable agronomic features. The results of a black shank survey published in 1994 reported that traces of a second race of *P. nicotianae* (designated race 1) were present in most fields with a history of black shank whether or not any *Php* gene variety had ever been grown there (3). The *Php* gene provides no control of race 1 of *P. nicotianae*. However, resistance based on FL-301 seems to provide similar black shank control to either race 0 or race 1. From 1986-1995, years of low to moderate black shank loss, growers continued to rely on metalaxyl, rotation, and FL-301 resistance. None of the few *Php* gene varieties introduced in this period became popular. The first high quality/high yield *Php* gene variety (NC-71) was introduced in 1995. This variety, which came to account for about 50% of the Georgia tobacco acreage, along with other new *Php* gene varieties (NC-72 & NC-297) soon became the sole means of controlling black shank. Mefenoxam, a purified more active isomer of the dual isomer metalaxyl was introduced in 1996. However, use of any chemical control dropped sharply due to the effectiveness of the *Php* gene in giving total control of race 0 of *P. nicotianae*. As early as 2001 black shank was showing signs of increase where the *Php* gene was used as the sole means of control. The increasing black shank was all found to be due to race 1 of the pathogen, presumably selected in mixed race populations by elimination of race 0 with the *Php* gene. Mefenoxam use began to increase and new varieties (NC-196 & GF-318) which seemed to have a better FL-301 resistance package than NC-71 became popular. Any weakness in the control program was hidden as loss potential continued to be low until 2013. There was a sharp increase in black shank loss in 2013. Growers relying on resistance alone (*Php* + FL-301) suffered heavy loss and had to finally realize that the *Php* gene would no longer control black at any location in Georgia due to the rise to dominance of race 1 of *P. nicotianae*. Growers using mefenoxam along with resistant varieties fared much better. The situation became worse in 2014. Very heavy rain during and just after transplanting resulted in much earlier than usual infection with the result being the highest black shank losses in 20+ years. In several cases where losses were very high to total mefenoxam had been used. Growers begin to raise questions about pathogen sensitivity to mefenoxam. Work began in 2014 to improve black shank control and re-educate growers about the biology of *P. nicotianae.*

METHODS:

2014 Mefenoxam sensitivity:

Three fields were selected for sampling where multiple applications of mefenoxam seemed to fail to control black shank. Tobacco stalks (15-20) showing typical wilting with an obvious black lower stalk lesion were collected in each field. Each stalk was cut into a 200-300 cm section with the advancing margin of the lesion about midway. The stalk sections were sent to North Carolina State University for an assay of mefenoxam sensitivity.

2014 variety trials:

The 2014 variety trials were intended to evaluate current grower preferences (NC-196 & GF-318) rated as having a moderate to high level of FL-301 resistance and compare them to three varieties (CC-143, GL-395 & NC-925) not in common use but also rated as having moderate to high FL-301 resistance. All trials were a randomized complete block with four single row reps of each test variety.

2015 variety trials:

The variety test program was expanded in 2015 to include 15 test varieties plus K-326 as a standard of low FL301 resistance. Also included at each site was, the thus far disappointing, NC-196 for further evaluation over a wider area. Further testing of NC-196 was due to its current place as the single most

popular tobacco variety grown in Georgia. Each 2015 trial was six test varieties chosen at random from a group of 15 plus K-326 and NC-196. Seven farm sites were used in these trials. Each test was a randomized complete block with four single row reps for each variety. It is important to note that only six of 15 test varieties were planted at each location.

2016 variety trials:

Four selections were made based on the 2015 trials for further testing in 2016. Two new varieties (PVH-1118 and PVH-2254) were added to the test group as unknowns. The test group was completed with K-326 (a standard of low FL-301 resistance) and K-346 (a standard of high FL-301 resistance). All eight varieties were set out in a randomized complete block with four single row reps of each variety at each of eight test locations.

2014 chemical control trial:

A trial comparing a single post-transplant application of mefenoxam (560 g/ha) to no treatment was conducted on three varieties at a single location. Mefenoxam was applied in a randomized complete block with four reps seven days after transplanting. The mefenoxam was sprayed on the bed surface at the base of the tobacco plants followed by incorporation with plowing.

2015 chemical control trials:

Flupicolide, marketed in the United States as Presidio, was approved for use on tobacco for the 2015 season. Trials were set up at two locations to compare flupicolide with mefenoxam for control of black shank in a two application program. The first application was to combine either flupicolide (140g/ha) or mefenoxam (280g/ha) with the transplant water. The second application was made at final plowing (layby) by spraying either flupicolide (140g/ha) or mefenoxam (560g/ha) on the bed surface and incorporate by plowing. Untreated controls were used at both steps. The transplant water treatments were laid out in a randomized complete block with three reps of each treatment. Each rep was four rows of tobacco for each treatment for a total of 12 rows of tobacco. The entire 36 rows were divided into three equal length sections. The final plowing treatments were applied in three reps laid over the 36 row plot in a Latin square (Figure1). Treatment was made by spraying the test product on the bed surface at the base of the tobacco plants followed by incorporation with plowing.

2016 chemical control trials:

Oxathiapiprolin, marketed in the United States as Orondis was approved for use on tobacco in 2016. The label requires application to be as a mix of oxathiapiprolin (70.2g/ha) plus mefenoxam (280g/ha). Trials were set up to compare the effectiveness of oxathiapiprolin, flupicolide, and mefenoxam to an untreated control as final plowing treatments for control of black shank. Transplant water treatments of either mefenoxam (280g/ha) or untreated were applied in a randomized complete block with four reps of each treatment. Each rep was four rows of tobacco for each treatment for a total of eight rows of tobacco. The entire 32 rows were divided into four equal length sections. The final plowing treatments, flupicolide (140g/ha), mefenoxam (560g/ha), or oxathiapiprolin (70.2g/ha) + mefenoxam (280g/ha), were applied along with an untreated control in four reps laid over the 32 row plot in a Latin square (Figure2). Treatment was made by spraying the test product on the bed surface followed by incorporation with plowing.

Black shank evaluation:

All trials were evaluated visually for black shank incidence beginning three weeks after transplanting and continuing every three weeks until 12-15 weeks after transplanting. Evaluations were done in early morning and plants were considered diseased if they were in a wilted condition at this time. A few plants were removed from the ground and further checked for other common symptoms including black rotted roots and an advancing black lesion on the lower stalk when black shank was first judged to be present.

RESULTS AND DISCUSSION:

2014 Mefenoxam sensitivity:

Ten isolates were recovered from samples from each of the three field sites and screened for sensitivity to mefenoxam. Two isolates were found to be sensitive while the remaining 28 were found to be very sensitive to mefenoxam. Heavy rainfall occurred during the entire 2014 transplanting season. Mefenoxam is known to be subject to leaching loss; this along with overwhelming early infection may account for the observed control failure.

2014 variety trials:

The principle varieties growers were using to combat black shank (NC-196 and GF-318) clearly failed to live up to expectations (Table 2). However, three varieties (CC-143, GL-395, and NC-925) farm tested for the first time were found to provide good black shank control at all three test locations (Table 3).

2015 variety trials:

A random selection of six out of 15 test varieties plus K-326 and K-346 were tested at each of seven locations. Very different black shank severity was seen among the seven test sites (Table 4). Some varieties ended up only in very high black shank incidence fields while others ended up only in very low black shank incidence fields. This made exact performance comparisons difficult and pointed up the limitations with the approach of testing different varieties at different locations. In spite of this four varieties (NC-606, NC-938, CC-1063, and PVH-1600) were selected for further testing. The data clearly showed the high yield and quality grower favorite, NC-196 to be of little value in terms of any useful black shank resistance (Table 4).

2016 variety trials:

Black shank incidence was generally less in 2016 than the past two years. Only three of the seven test locations developed enough black shank to collect useful data. The results showed NC-938, CC-1063 and PVH-1600 are worthy of further testing. Two new varieties, PVH-1118 and PVH-2254, entered into the trial as unknowns, did not show useful black shank resistance at any location. Our standard of high FL-301 resistance (K-346) performed well at all locations (Table 5).

2014 chemical control trial:

A single application of mefenoxam seven days after transplanting significantly ($p=0.05$) reduced black shank (Table 6). This result shows the value of luck in perfectly timing a treatment and would not lead to a recommended program. This field was not part of the mefenoxam sensitivity screen but did add data confirming isolates of *P. nicotianae* in Georgia are fully sensitive to mefenoxam.

2015 chemical control trials:

Flupicolide was compared to mefenoxam for black shank control at two locations (Table 7, 8). A scattered non uniform distribution of black shank compromised the final data at farm 2 (Table 8). However, both products performed equally at farm 1 (Table 8) offering a new option for black shank control. Our results generally confirm experiment station trials from both Georgia and North Carolina (data not shown).

2016 chemical control trials:

Trials in 2016 included oxathiapiprolin, another newly released option for black shank control. Oxathiapiprolin is required by label to be used as a mix with mefenoxam as part of a pathogen resistance management plan. Results obtained from the two test farms were not consistent (Table 9). Data from both farms show tobacco treated at final plowing developed less black shank than tobacco not treated at this time. Transplant water treatment was somewhat beneficial at farm 1 but not at farm 2 (Table 9). Flupicolide applied at final plowing gave the best control at farm 2 (Table 9). Data for farm 1 show all

three chemical options were equal if mefenoxam was applied in the transplant water. Black shank, like any soil borne disease, can be very non uniform in a field test site of the size (0.4-0.5 hectares) used in these trials. Uneven disease distribution was encountered at both locations and may have contributed to the less than clear cut results. Chemical treatments will perform best if application is timed so that uptake has occurred leaving a maximum active residue in the roots at the time soil saturation events leading to infection by *P. nicotianae* occur. If infection events occur before treatment or after a systemic chemical has been taken up and passed up the plant out of the root system control will be less to none. The two trials were neither transplanted nor treated on the same calendar date. They are located along the southern edge of the Georgia tobacco production area about 100k apart. Thus they should be expected to have different rainfall amounts as well as different rainfall patterns relative to treatment dates that could lead to inconsistent results.

CONCLUSIONS:

Tobacco varieties with better FL-301 resistance than traditional preferences have been identified through field testing. New chemical control options less subject to leaching loss than mefenoxam such as flupicolide and oxathiapiprolin are being tested. Moving forward we have improved our black shank management program. The future holds further promise for varietal resistance improvement as sources of resistance other than FL-301 or *Php* are developed. A 2013 trial screened breeding lines with new WZ genes. Lines with WZ genes showed superior black shank resistance under very high disease pressure (Table 10). Work is now under way to breed these genes into what can become commercial varieties.

REFERENCES:

1. Apple, J.L. 1967. Occurrence of race 1 of *Phytophthora parasitica* var. *nicotianae* in North Carolina and its implication in breeding for disease resistance. Tobacco Science 11:79-83.
2. Brown, B. *et al*. 2016. Flue-cured tobacco information. North Carolina State University Cooperative Extension Service. Raleigh, NC.
3. Csinos, A.S., and P.F. Bertrand 1994. Distribution of *Phytophthora parasitica* var. *nicotianae* races and their sensitivity to metalaxyl in Georgia. Plant Disease 78:471-474.
4. Lucas, G.B. 1975. Disease of tobacco, 3rd edition. Raleigh, NC.

FIGURE 1. Plot plan for the 2015 black shank control trials

Each row of ++++++++++++ = 4 rows of tobacco

TRANSPLANT WATER TREATMENTS:

Untreated	++++++++++++++++++	++++++++++++++++++	++++++++++++++++++++++
Flupicolide (140g/ha)	++++++++++++++++++	++++++++++++++++++	++++++++++++++++++++++
Mefenoxam (280g/ha)	++++++++++++++++++	++++++++++++++++++	++++++++++++++++++++++
Mefenoxam (280g/ha)	++++++++++++++++++	++++++++++++++++++	++++++++++++++++++++++
Untreated	++++++++++++++++++	++++++++++++++++++	++++++++++++++++++++++
Flupicolide (140g/ha)	++++++++++++++++++	++++++++++++++++++	++++++++++++++++++++++
Flupicolide (140g/ha)	++++++++++++++++++	++++++++++++++++++	++++++++++++++++++++++
Mefenoxam (280g/ha)	++++++++++++++++++	++++++++++++++++++	++++++++++++++++++++++
Untreated	++++++++++++++++++	++++++++++++++++++	++++++++++++++++++++++

LAYBY TREATMENTS:

TPW:	**mefenoxam (560g/ha)**	**flupicolide (140g/ha)**	**untreated**
Untreated	++++++++++++++++++	++++++++++++++++++	++++++++++++++++++++++
Flupicolide (140g/ha)	++++++++++++++++++	++++++++++++++++++	++++++++++++++++++++++
Mefenoxam (280g/ha)	++++++++++++++++++	++++++++++++++++++	++++++++++++++++++++++

	flupicolide (140g/ha)	**untreated**	**mefenoxam (560g/ha)**
Mefenoxam (280g/ha)	++++++++++++++++++	++++++++++++++++++	++++++++++++++++++++++
Untreated	++++++++++++++++++	++++++++++++++++++	++++++++++++++++++++++
Flupicolide (140g/ha)	++++++++++++++++++	++++++++++++++++++	++++++++++++++++++++++

	untreated	**mefenoxam (560g/ha)**	**flupicolide (140g/ha)**
Flupicolide (140g/ha)	++++++++++++++++++	++++++++++++++++++	++++++++++++++++++++++
Mefenoxam (280g/ha)	++++++++++++++++++	++++++++++++++++++	++++++++++++++++++++++
Untreated	++++++++++++++++++	++++++++++++++++++	++++++++++++++++++++++

FIGURE 2. Plot plan for the 2016 black shank control trials

Each row of ++++++++++++ = 4 rows of tobacco

TRANSPLANT WATER TREATMENTS:

Untreated	++++++++++++++	++++++++++++++++	++++++++++++++	++++++++++++++++
Mefenoxam (280g/ha)	++++++++++++++	++++++++++++++++	++++++++++++++	++++++++++++++++
Untreated	++++++++++++++	++++++++++++++++	++++++++++++++	++++++++++++++++
Mefenoxam (280g/ha)	++++++++++++++	++++++++++++++++	++++++++++++++	++++++++++++++++
Untreated	++++++++++++++	++++++++++++++++	++++++++++++++	++++++++++++++++
Mefenoxam (280g/ha)	++++++++++++++	++++++++++++++++	++++++++++++++	++++++++++++++++
Untreated	++++++++++++++	++++++++++++++++	++++++++++++++	++++++++++++++++
Mefenoxam (280g/ha)	++++++++++++++	++++++++++++++++	++++++++++++++	++++++++++++++++

FINAL PLOWING TREATMENTS:

TPW:	**mefenoxam**[1]	**flupicolide**[2]	**untreated**	**oxathiapiprolin**[3]
Untreated	+++++++++++++++	+++++++++++++++	+++++++++++++++	++++++++++++++++
Mefenoxam (280g/ha)	+++++++++++++++	+++++++++++++++	+++++++++++++++	++++++++++++++++
	oxathiapiprolin[3]	**untreated**	**mefenoxam**[1]	**flupicolide**[2]
Untreated	+++++++++++++++	+++++++++++++++	+++++++++++++++	++++++++++++++++
Mefenoxam (280g/ha)	+++++++++++++++	+++++++++++++++	+++++++++++++++	++++++++++++++++
	untreated	**oxathiapiprolin**[3]	**flupicolide**[2]	**mefenoxam**[1]
Untreated	+++++++++++++++	+++++++++++++++	+++++++++++++++	++++++++++++++++
Mefenoxam (280g/ha)	+++++++++++++++	+++++++++++++++	+++++++++++++++	++++++++++++++++
	flupicolide[2]	**mefenoxam**[1]	**oxathiapiprolin**[3]	**untreated**
Untreated	+++++++++++++++	+++++++++++++++	+++++++++++++++	++++++++++++++++
Mefenoxam (280g/ha)	+++++++++++++++	+++++++++++++++	+++++++++++++++	++++++++++++++++

FINAL PLOWING TREATMENTS:

[1] Mefenoxam applied at (560 grams/hectare)
[2] Flupicolide applied at (140 grams/hectare)
[3] Oxathiapiprolin applied at (70.2grams/hectare) **+** mefenoxam applied at (280 grams/hectare)

All final plowing treatments were made by spraying the test chemical onto the bed surface at the base of the tobacco followed by incorporation with plowing.

TABLE 1. Differential FL-301 black shank resistance in sister lines K-326 and K-346 illustrated in 2016 variety trials.

	Final % black shank[1]		
Variety	Farm 1[2]	Farm 2[2]	Farm 3[2]
K-326	44.3a	29.9a	15.0a
K-346	10.2 b	19.3 b	4.0 b

[1] Black shank incidence 12 weeks after transplanting.

[2] Means in a column followed by a different letter are significantly different (*p=0.05*).

TABLE 2. Black shank incidence in varieties preferred by growers in 2014.

		Final % black shank		
Variety	NCSU FL-301 Resistance rating[1]	Farm 1[2]	Farm 2[2]	Farm 3[2]
K-326[3]	24	55.4a	41.5a	21.9a
GF-318	17	50.3a	34.1a	13.6a
NC-196	13	31.0 b	32.4a	11.7a

[1] Black shank resistance ratings developed at North Carolina State University based on multiple trials. The lower the rating value the higher the FL-301 resistance is rated to be (2).

[2] Means in a column followed by a different letter are significantly different (*p=0.05*).

[3] A popular variety that serves as a standard of low FL-301 resistance.

TABLE3. Black shank control relative to K-326 shown by three test varieties in 2014.

		% Black shank control relative to K-326[1]		
Variety	NCSU FL-301 Resistance rating[2]	Farm 1	Farm 2	Farm 3
K-326	24	00.0a	00.0a	00.0a
CC-143	8	72.2 b	62.2 b	73.5 b
GL-395	13	50.8 b	67.2 b	72.6 b
NC-925	9	79.5 b	74.7 b	90.0 b

[1] Means in a column followed by a different letter are significantly different (*p=0.05*).

[2] Black shank resistance ratings developed at North Carolina State University based on multiple trials. The lower the rating value the higher the FL-301resistance is rated to be (2).

TABLE 4. Variation in black shank incidence among the 2015 variety trials as demonstrated by black shank incidence in K-326 and NC-196.

	Final % black shank (12 - 16 weeks after transplanting)[1]						
Variety	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7
K-326	7.7a	12.3a	19.8a	21.4a	34.8a	58.8a	84.4a
NC-196	5.2a	11.5a	7.3 b	12.4 b	30.9a	60.8a	82.5a

[1] Means in a column followed by a different letter are significantly different (*p=0.05*).

TABLE 5. Results of 2016 black shank variety resistance trials.

		Final % black shank[1]			
Variety	NCSU FL-301 Resistance rating[2]	Farm 1	Farm 2	Farm 3	Mean % control Relative to K-326
K-326	24	44.3	29.9	15.0	00.0
PVH-1600	na[3]	13.3	23.2	12.1	45.5
NC-938	na[3]	15.8	18.0	6.1	55.1
K-346	6	10.1	19.3	4.0	62.3
CC-1063	12	11.2	14.5	7.0	63.3
LSD (*p=0.05*)	---	*17.8*	*7.6*	*6.8*	*13.1*

[1] Black shank incidence 12 weeks after transplanting.
[2] Black shank resistance ratings developed at North Carolina State University based on multiple trials. The lower the rating value the higher the FL-301 resistance is rated to be (2).
[3] These are new varieties and data is insufficient to generate resistance ratings at this time.

TABLE 6. Control of black shank with a single application of mefenoxam[1].

	Final % black shank[2]	
variety	Untreated	Mefenoxam
K-326	21.9a	3.3 b
GF-318	13.6a	1.3 b
NC-196	11.7a	4.5 b
Mean	15.7a	3.0 b

[1] Mefenoxam applied (560 grams/hectare) seven days after transplanting by spraying on the bed surface at the base of the plants and incorporated with plowing.
[2] Numbers in the rows followed by a different letter are significantly different (*p=0.05*).

TABLE 7. Comparison of flupicolide (140 grams/hectare) and mefenoxam (280 grams/hectare) applied in the transplant water for control of early season black shank in 2015.

	% Black shank at final plowing[1]	
Treatment	Farm 1[2]	Farm 2[2]
Untreated	5.3a	7.3a
Mefenoxam	2.5 b	1.3 b
Flupicolide	1.0 b	3.1 b

[1] 35 days after transplanting
[2] Means in a column followed by a different letter are significantly different (*p=0.05*).

TABLE 8. Comparison of flupicolide (140 grams/hectare) and mefenoxam (560 grams/hectare) applied 35 days after transplanting for control of late season black shank.[1]

	Final % black shank[2]	
Treatment	Farm 1	Farm 2[3]
Untreated	74.5a	23.0a
Mefenoxam	31.3 b	14.0a
Flupicolide	26.5 b	18.2a

[1] Treatments were applied by spraying chemical on the bed surface at the base of the plants and incorporation with plowing.
[2] Black incidence 12 weeks after transplanting. Means in a column followed by a different letter are significantly different (*p=0.05*).
[3] Black shank at this farm developed in a very non-uniform pattern.

TABLE 9. Chemical control of black shank at two locations in 2016.

Treatment		Final % black shank[1]	
TPW[2]	x FP[3]	Farm 1	Farm 2
Ut	x Ut	66.0	28.4
Mf	x Ut	51.8	24.9
Ut	x Fp	51.0	**07.4**
Ut	x Mf	45.9	21.5
Ut	x Ox+Mf	**37.8**	**18.3**
Mf	x Fp	**37.6**	**05.7**
Mf	x Mf	**32.6**	27.7
Mf	x Ox+Mf	**29.8**	24.1
LSD (0.05)		*14.4*	*09.4*

[1] % Black shank 12 weeks after transplant. In each column values in **bold** looked the best at seasons end.
[2] Treatment combined with transplant water; Ut = untreated, and Mf = mefenoxam (280 grams/hectare).
[3] Treatment applied at final plowing by spraying test chemical on the bed surface at the base of the plants followed by incorporation with plowing; Ut = untreated, Fp = flupicolide (140 grams/hectare), Mf = mefenoxam (560 grams/hectare), and Ox+Mf = oxathiapiprolin (70.2 grams/hectare) + mefenoxam (280 grams/hectare).

TABLE 10. Black shank incidence in various tobacco varieties compared to breeding lines carrying WZ gene constructs.

Variety	% Black shank[1]
1071[2]	99.3a
K-326[3]	99.3a
NC-71[3]	88.8a
NC-196[3]	80.0a
K-346[4]	37.2 b
WZ lines[5]	7.0 c

[1] Final % black shank 16 weeks after transplanting. Values followed by a different letter are significantly different (*p=0.01*).
[2] 1071 is a breeding line source of the *Php* gene, but has no FL-301 resistance. It is a good indicator for the presence of race 1 of *Phytophthora nicotianae*.
[3] The varieties K-326 (low FL-301 resistance; no *Php* gene), NC-71 (low FL-301 resistance but with the *Php* gene), and NC-196 (thought at this time to have high FL-301 resistance and with the *Php* gene) made up >75% of the Georgia tobacco acreage in 2013. Variety trials in 2014 and 2015 confirmed a low level of FL-301 resistance in NC-196.
[4] K-346 is a standard of high FL-301 resistance but does not carry the *Php* gene.
[5] Data is a mean for 12 breeding lines.