COTTON AND PEST RESPONSE TO NEMATICIDE-INSECTICIDE COMBINATIONS APPLIED AT-PLANTING ACROSS DIFFERENT SOIL TEXTURES IN A SPATIALLY VARIABLE FIELD

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Abstract

Use of at-planting insecticide and nematicides for early season crop protection may provide benefits to earliness and yield potential of cotton; however, costs of these protectants may be prohibitively high in production systems where managers are focused on reducing costs. There may be benefits using these products in a site-specific approach in spatially variable fields; however, there is limited information to guide managers in precision application. Baseline data from field experiments is needed in order to develop recommendations for site-specific applications. In this 2016 field trial in a commercial field in NE Arkansas, we investigated both plant and pest response to four at- planting treatments in a spatially variable field suitable for site-specific management. A base seed-applied insecticide-nematicide of Aeris® (imidacloprid + thiodicarb), was used across all treatments. The four treatments were 1) Aeris, 2) COPeO Prime (fluopyram) + Aeris, 3) Velum Total (imidacloprid + fluopyram) + Aeris, and 4) AgLogic (aldicarb) + Aeris. The experiment was arranged in a randomized strip plot design with 3 replications. Each treatment was planted in 12 consecutive rows using a 4-row research planter equipped to apply in-furrow treatments. Plant, insect pest, nematode and soil monitoring activities were extensive through the season and included soil collections at planting and at first flowers, plant root gall assessments at first flowers, early season whole plant washes for thrips assessments which also included leaf area determinations, weekly plant bug sampling and COTMAN plant monitoring. Delineation of soil texture based management zones was established from indirect measurements using a Veris 3150 EC Surveyor instrument®. Sample points for the strip trial were based on soil texture classes of loamy sand and coarse sand. Nematode assessments made from at-planting soil collections indicated root-knot and reniform nematode densities were at threshold levels previously reported to reduce yield by 10% or greater. For the season, there were sub-threshold insect pest densities (thrips and plant bugs). Generally, lowest insect pest numbers were associated with AgLogic treatments. Results indicate there were significant improvements in stand establishment, early season leaf area, and pre-flower nodal development associated with Velum Total and AgLogic treatments across both soil textures compared to Aeris alone and COPeO + Aeris. Overall, yields were higher for plants in loamy sand compared to plants in coarse sand. There were no significant maturity, yield, or fiber quality differences among insecticide/nematicide treatments. The on-farm practicality of a pest management program with site-specific use of at-planting protectants will depend on spatial management capacity of the farm, including adequate equipment and technical expertise, as well as size of within-field areas associated with reduced yield potential, and the total application costs for protectants.

Introduction

Crop protection tools for preventative chemical control include seed treatments and in-furrow applications of insecticide and fungicide. If effectively applied, these treatments can lessen pest-induced injury from early season pests of cotton including thrips and nematodes; however, when their costs exceed value of the associated yield or quality gains, even the most efficacious products are too expensive for profitable production. Expanded use of precision, site-specific approaches rather than broadcast applications could focus product delivery to field areas where preventative control is economically appropriate. Practical guidelines are needed for crop managers to expand their use of site-specific applications of protectants. This includes use of management zones, a site- specific approach where a modified input or practice is installed to mitigate a known yield-limiting factor in an identified sub-region of a spatially variable field (Doerge 1999).

Cotton researchers previously have evaluated site-specific application of protectants for suppression and control of root-knot nematodes using management zones based on soil physical properties, particularly soil texture (Wheeler et al 1991, Wolcott 2007, Ortiz et al 2012). Overstreet et al. (2005) compared nematicide response across management zones and reported increased yield associated with protectants only in coarser soil textures. Monfort et al. (2007) observed reported a strong relation between root-knot nematode population density, soil texture and yield. In Georgia cotton, Ortiz et al. (2010, 2012) evaluated variable rate applications of nematicides in management zones delineated using field measurements of soil electrical conductivity (apparent soil EC) as surrogate data for soil texture. The authors suggested that significant differences in management zones must exist for the zone application of nematicides to produce expected differential nematode control and yield benefits.

In the irrigated, precision-leveled, Midsouth cotton production fields common in the Mississippi Delta, physical properties of the alluvial soils greatly impact plant carrying capacity -- the boll load that reduces fruit retention and slows squaring node production to zero (Hearn and Da Roza 1985). Carrying capacity also is limited with poor growing conditions or limited resources (e.g. compacted soils, drought or nutrient deficiency). Soil EC maps coupled with yield monitor data can be used to help confirm that soil properties are a primary cause of limited carrying capacity.

Carrying capacity is an important component in plant compensatory response and recovery following insect pest induced injury. Typically, high carrying capacity plants will have high compensation capacity, and low carrying capacity plants will have reduced recovery potential (Sadras and Felton 2010; Teague 2016). In fields where heterogeneous soils have been identified as the primary cause of limited carrying capacity, one could expect that the associated patterns of spatial variability of compensation capacity also would correspond to patterns of spatial variation in crop benefit from use of protectants. A better understanding of these relationships would be helpful as we formulate approaches to expand use of site-specific pest management.

In this 2016 field trial in a commercial field in NE Arkansas, we investigated both plant and pest response to four at-planting insecticide/nematicide treatments in a spatially variable field suitable for site-specific management. Our overall goal in this research is to develop, evaluate and deliver practical guidelines to crop managers to improve and expand their use of site-specific applications of protectants. Specific objectives for this study were: 1) examine plant response to seed treatments and in-furrow insecticide/nematicide combinations across different soil textures, 2) quantify pest insect and nematode abundance and impact on earliness, yield and fiber quality with at-planting protectants, and 3) increase understanding of how management zones based on soil EC maps can be used to improve efficiency of pest management practices

Materials and Methods

The study was conducted in a 17 acre field on Wildy Family Farms in Mississippi County in Northeastern Arkansas. The production field had been in continuous cotton production for more than 40 years. Cultivar ST 4848 GLT was planted on raised beds spaced at 38 inches 10 May 10 at a seeding rate of 42,000 seed/ac (3 seeds/ft of row) using a 4-row research planter equipped to apply in-furrow treatments. All seed had a base insecticide/fungicide of Aeris (thiodicarb +imidacloprid). For the experiment, there were four treatments: 1) Aeris (seed treatment), 2) Aeris + COPeO (fluopyram) (seed treatment), 3) Aeris + Velum Total (14 oz/A liquid in-furrow) (fluopyram+imidacloprid), and 4) Aeris + AgLogic (aldicarb) (5 lb/A granules in-furrow). The experiment was arranged in a randomized plot design with 3 replications. Plots were 12 rows wide and 565 ft long (one 12-row swath through the field was ca. 0.5 acres). Other than the at-planting treatments, all other production practices including land preparation, fertilizer application, irrigation and pest control were performed by the cooperating producers following their standard management regime and using their equipment (Table 1).

Sampling Protocols and Site Selection

Plant, insect pest, nematode and soil monitoring activities were extensive through the season. Plot plan and sample points are shown on the deep EC map (**Error! Reference source not found.**). A stratified, systematic sampling design was used to select the plant and pest sampling sites in each 12-row strip. Strata were defined by soil EC measurements classified as High and Low ranges of soil EC categories in the loamy sand and coarse sand soil textures, respectively. Delineation of soil texture was established from indirect measurements using a Veris 3150 EC Surveyor instrument® (Veris Technologies, Inc., Salina, KS). Sample points were identified within each strata, marked with flags and referenced with GPS coordinates. These reference points were used to set 10 ft of row for harvest areas. No further sampling was conducted in these harvest areas to avoid thigmonasty which could confound yield and fiber quality assessments. To avoid potentially confounding effects of compaction associated with harvest operations, yield sample rows were positioned in either row 3 or 4 of the 12-row plot. Sampling was performed in proximity of these reference points including plant stand determinations and soil samples. Insect scouting and plant monitoring occurred in rows 3, 4, 9, and 10. Stand counts were made 31 May at 21 days after planting (DAP). Plant stand densities were determined in two, 3-ft transect samples made across each soil textural zone over 12 rows.

Table 1. Dates of planting, irrigation, sampling, foliar insecticide application, and harvest for the 2016 study, Wildy Family Farms, Manila, AR.

Operation	Date	Days after planting
Date of planting	10 May 2016	
Stand counts	31 May	21
Soil samples (nematodes)	16 May, 18 July	6, 69
Leaf Area Index	24 May, 7 June	14, 28
Producer-applied foliar insecticides	1, 14 June (dicrotophos, acephate); 30 June, 7 July (sulfoxaflor), 1 Aug (dicrotophos + bifenthrin)	22, 35, 51, 58, 83
Furrow irrigation	17, 23 June, 1, 8 July, 12 Aug	38, 44, 52, 59, 94
Hand harvest	16-Oct	155
Machine harvest	28-Oct	171

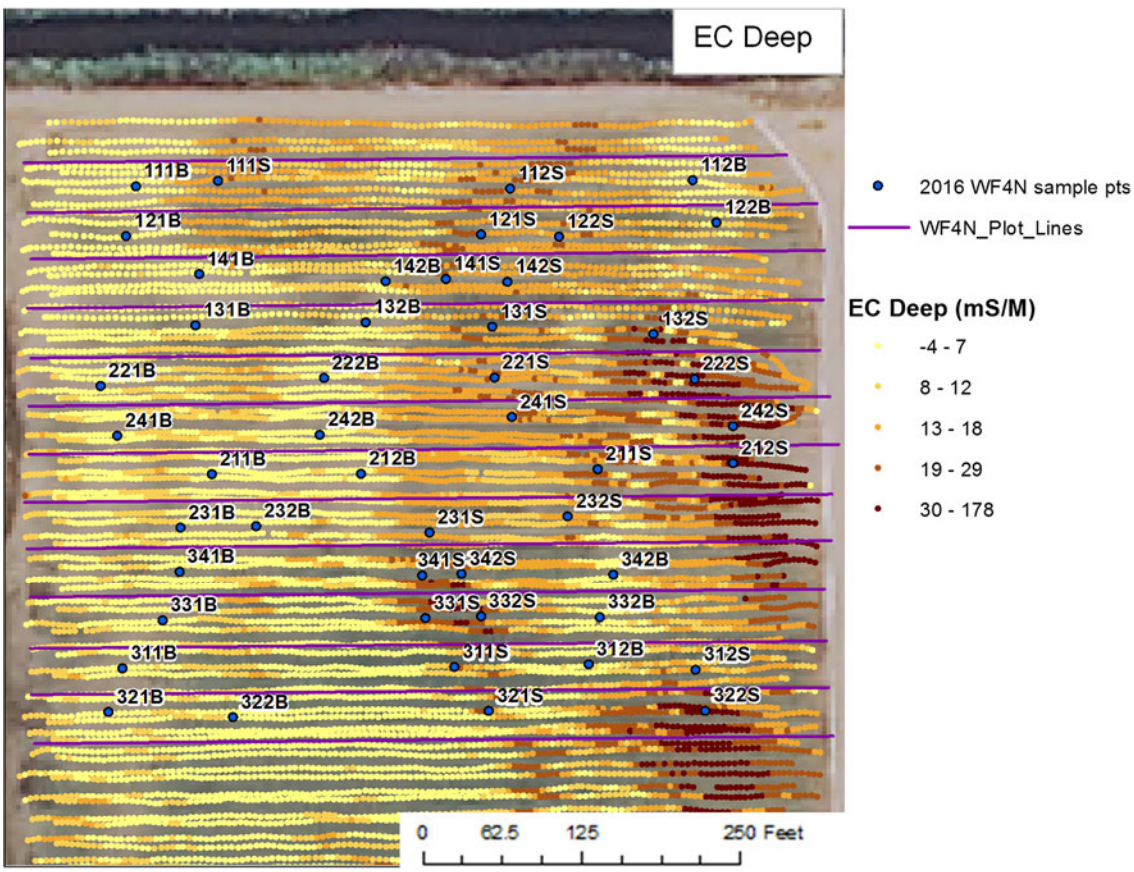

Figure 1 Field layout overlaid on soil EC map (deep) with sample points indicated for each 12-row wide treatment strip; there were 2 points for coarse sand (B) and 2 points for loamy sand (S) – Manila, AR, 2016.

Soil samples for nematode assessments were collected at designated sample points at 6 DAP and again 69 DAP (week of observation of first flowers). Each sample consisted of 15 soil cores collected within the seed bed and root zone to 8” depths using an Oakfield Tube Sampler soil probe. Samples were sent to the Arkansas Nematode Diagnostic Laboratory at the University of Arkansas Southwest Research and Extension Center in Hope, AR. Plants were collected and whole plant washes for thrips made 24 May at 14 DAP. These plants were also used for leaf area index (LAI) determinations were made using a LI-3100C Area Meter (LI-COR Biosciences, Lincoln, NE). Additional plant collections for LAI determinations were made 9 June (30 DAP). Plant biomass (oven dry weights of whole plants sans root) were also measured. Plant collections also were made at 69 DAP, and assessments made at the A-State Teague Lab for plant height, mainstem nodes, and root gall assessments.

Weekly plant monitoring included evaluations of plant main-stem nodal development, height, and first position square and boll retention using standard COTMAN® sampling methods (Oosterhuis and Bourland 2008). Monitoring continued through the effective squaring and flowering periods (Teague 2016). Efficient plant monitoring requires a standard with which to compare actual plant growth. In the COTMAN system, growth curves are generated from field data collections and consist of squaring nodes plotted against days after planting. They are compared to the COTMAN standard curve, which is assumed to represent an optimum combination of early maturity and high yield (Bourland et al 2008). The standard curve shows main stem squaring nodes through a season, ascending at a pace of one node each 2.7 days through first flower at 60 days after planting, and then descending to physiological cutout at 80 days. Rate of squaring node development after first flower declines in response to an increasing boll load until physiological cutout. The post-flower decline in terminal growth is easily measured as NAWF (nodes above white flower). Physiological cutout is defined as when the plant population reaches an average of NAWF = 5.

Yield assessments were based on hand-harvest in the 10ft subplot, as well as from the cooperating producers from John Deere 7600 cotton picker equipped with calibrated yield monitor with GPS receiver to attain site-specific lint yield. Hand-picked bolls (40 consecutive bolls throughout plants including both upper and lower canopy bolls) were ginned on laboratory gin, and fiber set to the Texas Tech Fiber and Biopolymer Research Institute for HVI evaluations. Point sample data from the experiment were analyzed as a split plot design with seeding rates considered main plots and soil textural classes considered sub-plots, and hand-harvest lint yield means were separated using Fisher's Protected LSD test at the P= 0.05. Field level yield data, acquired with the yield monitor, were post-calibrated using final module weights retrieved from the gin. Measurements were taken from a harvest swath (6 rows) in the center of each plot running the length of the field. Georeferenced data layers from soil EC and yield monitor were joined. A two-way factorial treatment structure was used for analysis of the yield monitor measured yield with nematicide/insecticide treatment and block effect and soil EC classifications included as a co-variate. For the final analysis, soil EC values were stratified into two classes -- coarse sand (deep <7 mS/m) and sandy loam (> 8 mS/m). These categories were based on five classes calculated from georeferenced soil EC data distributions using ArcGIS©10.2 (ESRI; Redlands, CA). The EC classes were set using five natural breaks, with the four highest EC classes combined into the loamy sand category, and lowest soil EC class categorized as coarse sand. Class categories were based on previous field experience as well as historical yield and plant monitoring data. The coarse sand class encompassed ca. 34% of the field. Data were analyzed using PROC GLM and MIXED (SAS Institute; Cary, NC).

Results

The early start of the 2016 production season in Northeast Arkansas was characterized by cool temperatures and wet conditions during stand establishment. Precipitation levels were lower than average in June and July (Table 2). There were five furrow irrigations applied during the crop season (Table 1).

Table 2. Monthly precipitation (inches) measured at the study site for the 2016 season compared with 30 year average for the county – 2016, Manila, AR.

Month	30 year Average	2016 Rainfall	Departure
	---------------------inches---------------------		
May	5.37	5.7	0.33
June	3.99	2.55	-1.44
July	4.04	3.88	-0.16
August	2.36	4.16	1.8
Total Season	20.51	16.29	-4.22

Plant stand densities measured at 21 DAP showed great variability among treatments with higher plant population density associated with plants in loamy sand compared to coarse sand (P=0.03), and also higher plant stand density in the AgLogic and Velum Total treatments compared to either the COPeO or Aeris treatment (Figure 2).

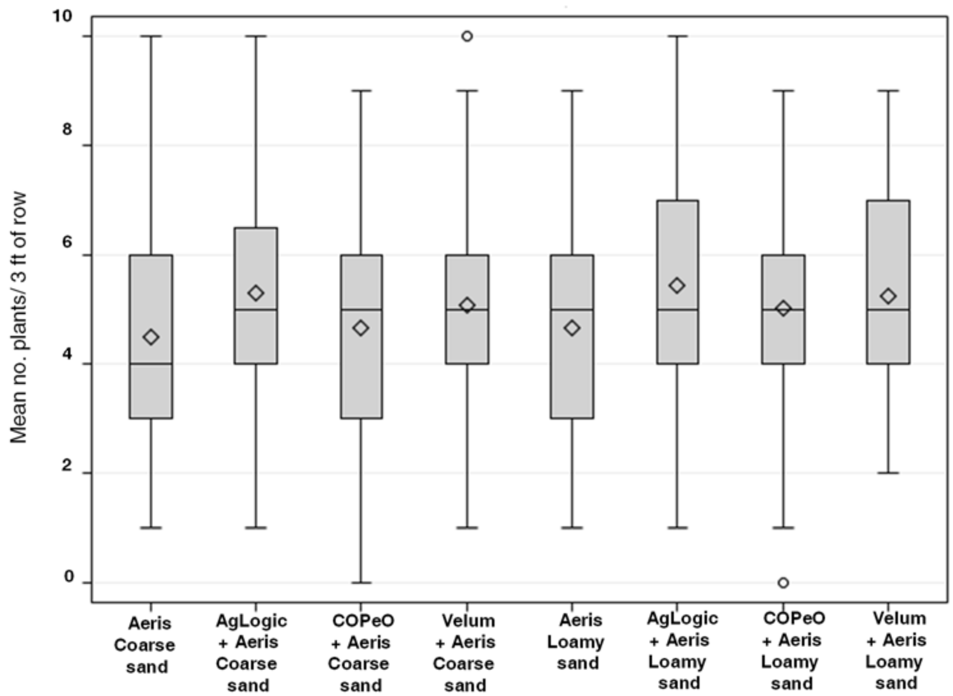

Figure 2. Plant stand density, measured as mean no. plants per 3 ft of row measured in two, 3-ft transects across the 12-row plots on 21 May – plant stand density differed among soil textures and insecticide/nematicide treatments (P=0.02) with no significant interactions. Boxes represent 50% quartile; diamonds within the box depict means, and the line is the median value – Manila, AR, 2016.

Thrips infestation levels were low in the 2016 season with numbers well under established Extension-recommended action levels for initiating foliar applications for suppression. We did observe significant differences among insecticide/nematicide treatments and soil textures observed in plant wash samples collected at 14 DAP (Figure 3). Highest mean thrips numbers were associated with plants collected in coarse sand from Aeris only treated seed.

Plant leaf area measures at 14 and 30 DAP indicate that there was variability in plant development in the coarse and loamy sand soil textures and with different at-planting treatments (Table 3). No differences were apparent at 14 DAP; however, by 30 DAP, LAI measures were lowest for plants in coarse sand and Aeris only treatment. Greatest LAI values were observed with plants in loamy sand with in-furrow Velum Total or AgLogic. Plant measurements at 70 DAP showed similar trends in plant height, counts of main stem sympodia, and total plant dry weight biomass (Table 4). Assessments made at 69 DAP included root-knot nematode gall ratings. Counts indicated overall low incidence of root-knot infestation, but there were differences among treatments with lowest numbers of galls observed for the AgLogic treatment (Table 4). Soil sampling results for nematodes at planting and at 69 DAP had shown that overall levels of all nematodes were moderately low; however, both root-knot and reniform nematode levels were at levels that Mueller et al. (2012) associated with potential risks of 10% yield loss (40 and 50 per 100 cm3 sample in sandy loam soils, for root-knot and reniform, respectively) (**Error! Reference source not found.**).

COTMAN growth curves from all treatments in each soil classification for the first 60 DAP, were positioned the right of the standard target development curve indicating a delay in the onset of sympodial development (Figure 4). First squaring nodes are expected by 35 days after planting, but cool temperatures will delay emergence and subsequently, the initiation of the first squares. COTMAN growth curves for plants in both soil textures for each at-planting treatment show that plants in coarse sand lagged somewhat behind in preflower development. Squaring node counts at approximately first flowers (~NAWF value) provide a measure of available fruiting sites as the crop transitions from squaring node development to effective flowering and boll maturation. Typically, plants with lower NAWF values at first flower have lower yield potential. In this study, first flowers were observed at 64 DAP, and highest mean number of squaring nodes per plant were associated with Velum Total and AgLogic treated plants in loamy sand (8.2 squaring nodes/plant for both treatments in loamy sand) (Figure 5). Plants in coarse sand with Aeris only and Aeris+COPeO produced an average of 6.8 nodes per plant. After first flowers, values for weekly NAWF counts did not decline as expected in relation to the standard target development curve. This delayed maturity was related to cloudy, rainy, overcast weather conditions during effective flowering period likely resulted in delayed maturity. Late season growth curves were very similar for plants among treatments and soil textures, and physiological cutout (NAWF=5) was ca. 90 DAP for all treatments.

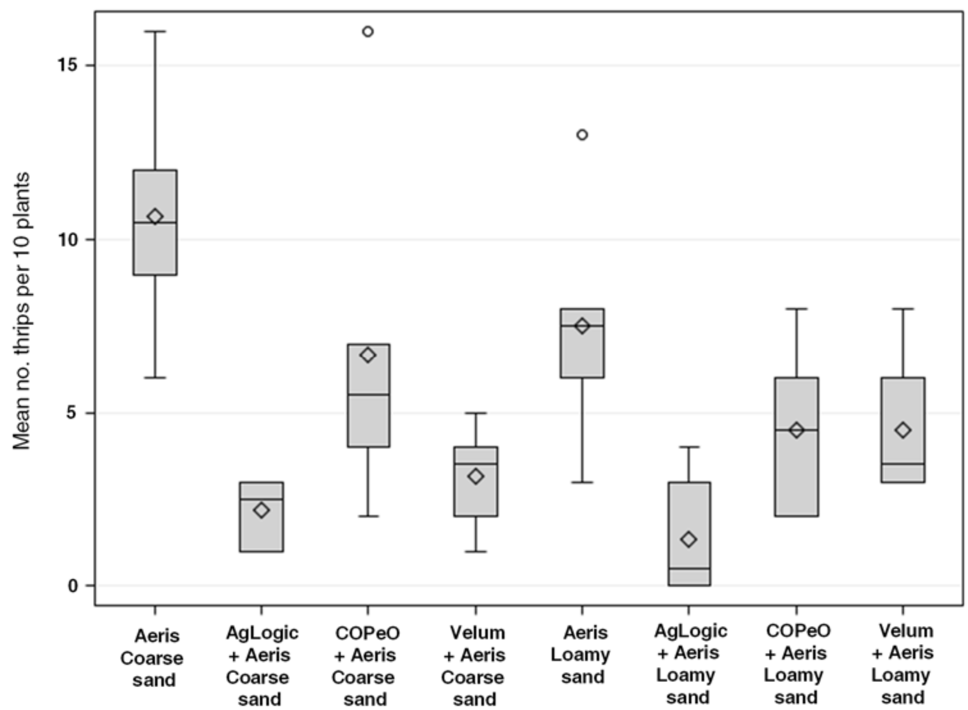

Figure 3. Thrips spp.(larvae and adults) per 10 plants measured from whole plant wash from samples collected 14 DAP differed among soil textures and insecticide/nematicide treatments (P<0.05). Boxes represent 50% quartile; diamonds within the box depict means, and the line is the median value – – Manila, AR, 2016.

Table 3. Measurements of leaf area index from 10 plant samples collected at 14 and 30 DAP for nematicide / insecticide trial – 2016, Manila, AR.

		Leaf area index (days after planting)	
Soil Texture	Treatment	14	30
	Aeris	109.9	189.3
Coarse Sand	COpeO + Aeris	111.1	239.3
	Velum Total + Aeris	110.1	259.7
	AgLogic +Aeris	101.4	208.7
Loamy Sand	Aeris	111.4	241.0
	COpeO + Aeris	100.5	262.2
	Velum Total + Aeris	104.2	287.6
	AgLogic +Aeris	97.2	290.7
Pr>F	*soil texture*	*0.13*	*0.03*
	at-planting treatment	*0.09*	*0.42*
	*at-planting treatment*soil texture*	*0.6*	*0.60*

Table 4. Root-knot gall counts per plant among treatments, along with plant height, number mainstem sympodia, biomass (dry weight) for plants collected either in coarse sand or loamy sand at 70 days after planting (19 July) in 2016 Nematicide/Insecticide trial, Manila, AR.

Soil Texture	Treatment	Height (cm)		Sympodia (no.)		Biomass (g)		Galls (no.)	
Coarse Sand	Aeris	29.2	E	5.8	D	10.2	C	3.9	A
	COpeO + Aeris	29.9	E	6.4	CD	13.0	C	1.3	BCD
	Velum Total + Aeris	34.7	D	6.5	D	12.4	C	2.1	BCD
	AgLogic +Aeris	33.9	D	6.4	CD	13.8	C	0.6	DE
Loamy Sand	Aeris	57.2	C	8.4	B	44.7	B	2.0	BCD
	COpeO + Aeris	55.5	C	8.5	AB	49.3	AB	1.1	CDE
	Velum Total + Aeris	65.0	A	9.1	A	39.5	B	0.9	DE
	AgLogic +Aeris	61.1	B	8.4	B	59.3	A	0.2	E
Pr>F	*soil texture*	*<0.0001*		*<0.001*		*0.002*		*<0.001*	
	at-planting treatment	*<0.0001*		*0.020*		*<0.001*		*0.150*	
*at-planting treatment * soil texture*		*0.030*		*0.410*		*0.060*		*0.270*	

Table 5. Mean no. nematodes per 100 cc soil from samples collected on 16 May (6 DAP) and 18 July (69 DAP) among insecticide /nematicide treatments and soil textures – 2016, Manila, AR.

Sample date& Soil texture	Treatment	Dagger	Reniform	Spiral	Stub root	Stunt	Root-knot
6 DAP		--------------------no per 100 cc soil--------------------					
Coarse Sand	Aeris	0.0	147.3	31.7	0.0	50.7	51.0
	COpeO + Aeris	0.0	0.0	31.8	6.3	0.0	50.8
	Velum Total + Aeris	6.3	6.3	95.8	6.3	89.3	63.8
	AgLogic +Aeris	0.0	0.0	76.7	6.3	6.3	31.7
Loamy Sand	Aeris	0.0	0.0	102.2	0.0	12.7	63.8
	COpeO + Aeris	0.0	83.0	222.2	6.3	31.7	44.5
	Velum Total + Aeris	0.0	25.5	140.7	0.0	25.3	76.7
	AgLogic +Aeris	0.0	0.0	179.2	0.0	12.7	57.7
Pr>F	*soil texture*	*0.32*	*0.63*	*0.00*	*0.35*	*0.36*	*0.59*
	at-planting treatment	*0.41*	*0.16*	*0.47*	*0.62*	*0.22*	*0.82*
	*at-planting treatment * soil texture*	*0.41*	*0.01*	*0.39*	*0.83*	*0.40*	*0.96*
69 DAP		--------------------no per 100 cc soil--------------------					
Coarse Sand	Aeris	0.0	0.0	31.7	0.0	0.0	44.7
	COpeO + Aeris	7.6	100.0	30.4	0.0	15.2	253.2
	Velum Total + Aeris	0.0	44.8	51.7	0.0	12.7	70.2
	AgLogic +Aeris	0.0	6.3	89.5	0.0	0.0	108.7
Loamy Sand	Aeris	0.0	0.0	63.7	0.0	0.0	57.3
	COpeO + Aeris	0.0	0.0	102.2	19.0	19.2	12.7
	Velum Total + Aeris	0.0	0.0	51.0	0.0	6.3	50.8
	AgLogic +Aeris	0.0	134.5	50.5	6.3	31.8	50.8
Pr>F	*soil texture*	*0.28*	*0.99*	*0.67*	*0.01*	*0.40*	*0.13*
	at-planting treatment	*0.34*	*0.54*	*0.54*	*0.12*	*0.39*	*0.70*
	*at-planting treatment * soil texture*	*0.34*	*0.19*	*0.44*	*0.01*	*0.34*	*0.32*

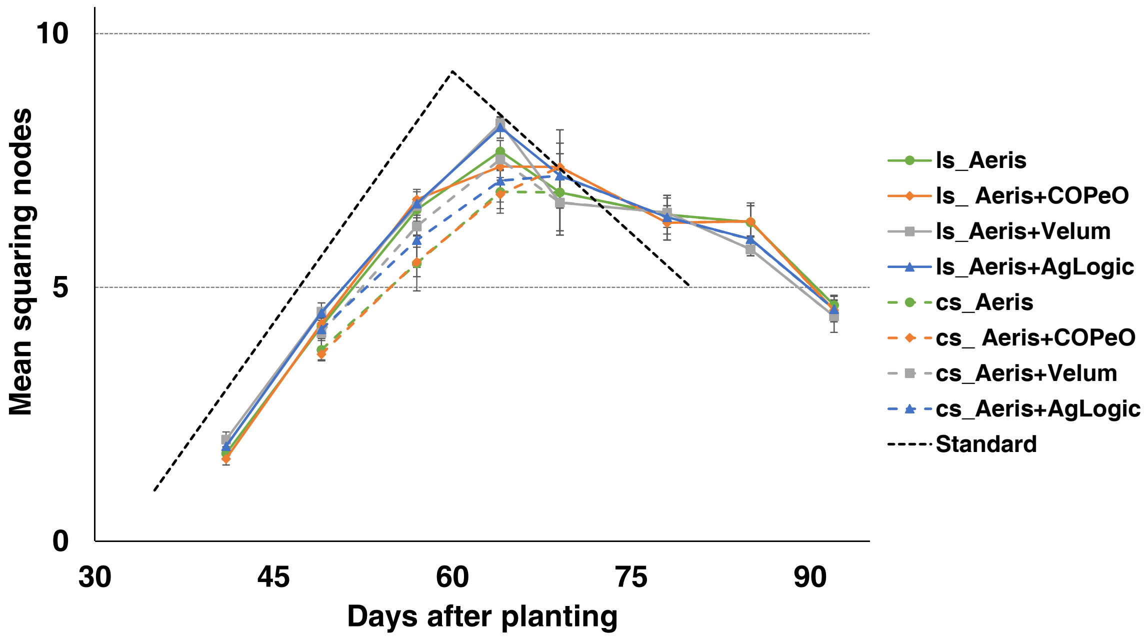

Figure 4. COTMAN growth curves for plants in each nematicide treatment in two different soil textures - coarse sand (cs) or loamy sand (ls). Note the deviation from expected slope of growth curves for plants in both soil textures beginning 70 days after planting – 2016, Manila, AR.

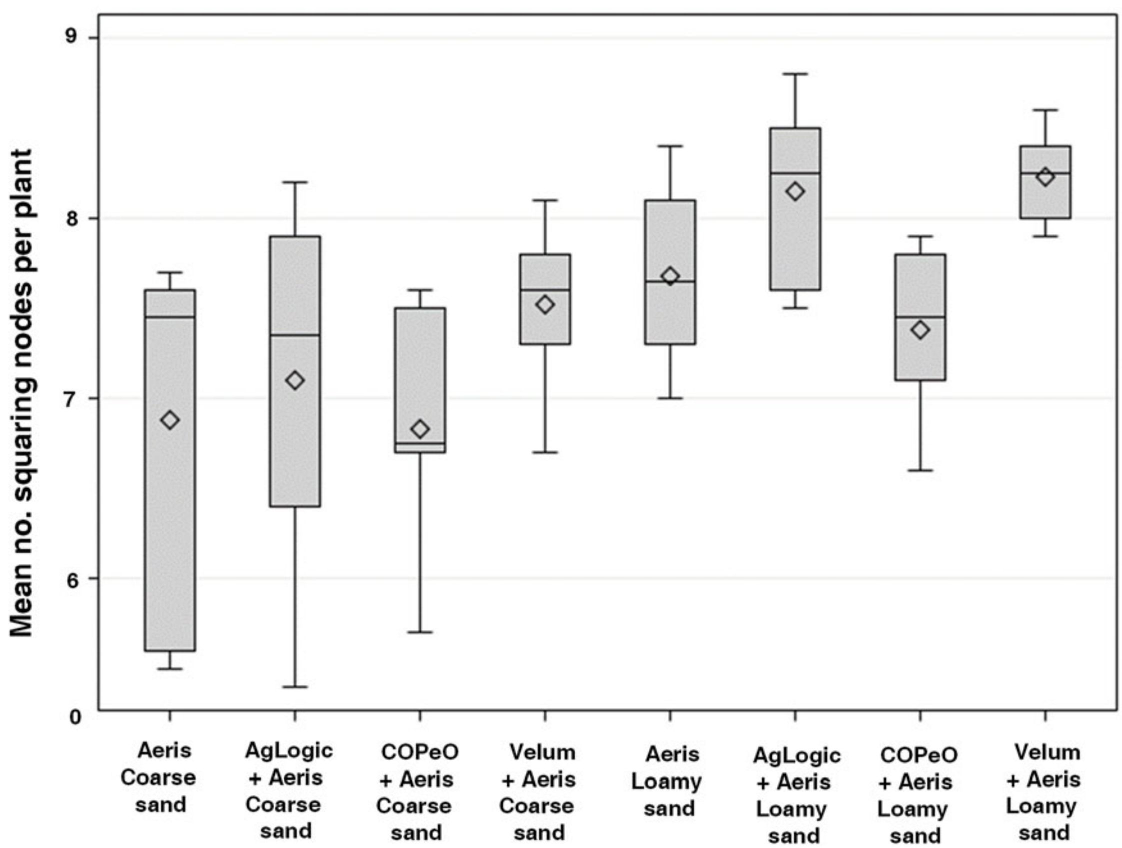

Figure 5. Squaring nodes per plant at the time of first flowers (64 DAP) observed for plants in coarse and loamy sand for each of the at-planting insecticide/nematicide treatments Boxes represent 50% quartile; diamonds within the box depict means, and the line is the median value – – Manila, AR, 2016

Yield

Analysis of yield data from hand harvested (10 ft of row) sample sites indicated in no differences in lint yield among at-planting nematicide/insecticide treatments (P=0.34); however, yield was affected significantly by soil texture. Plants in the coarse sand zone produced significantly lower mean lint yield (967 lbs/ac) compared to plants in the loamy sand (1354 lbs/ac) of the field (Figure 6). Interactions with at-planting treatment and texture were not significant (P=0.17). Analysis results for yield monitor measured yields indicated significantly higher yields (P=0.001) in the loamy sand classification (EC > 8 mS/M) compared to the coarse sand classification (EC< 7 mS/m) (Figure 7). There was no significant differences associated with at planting nematicide / insecticide treatments or interactions with treatments (P=0.29) and soil texture (P>0.25).

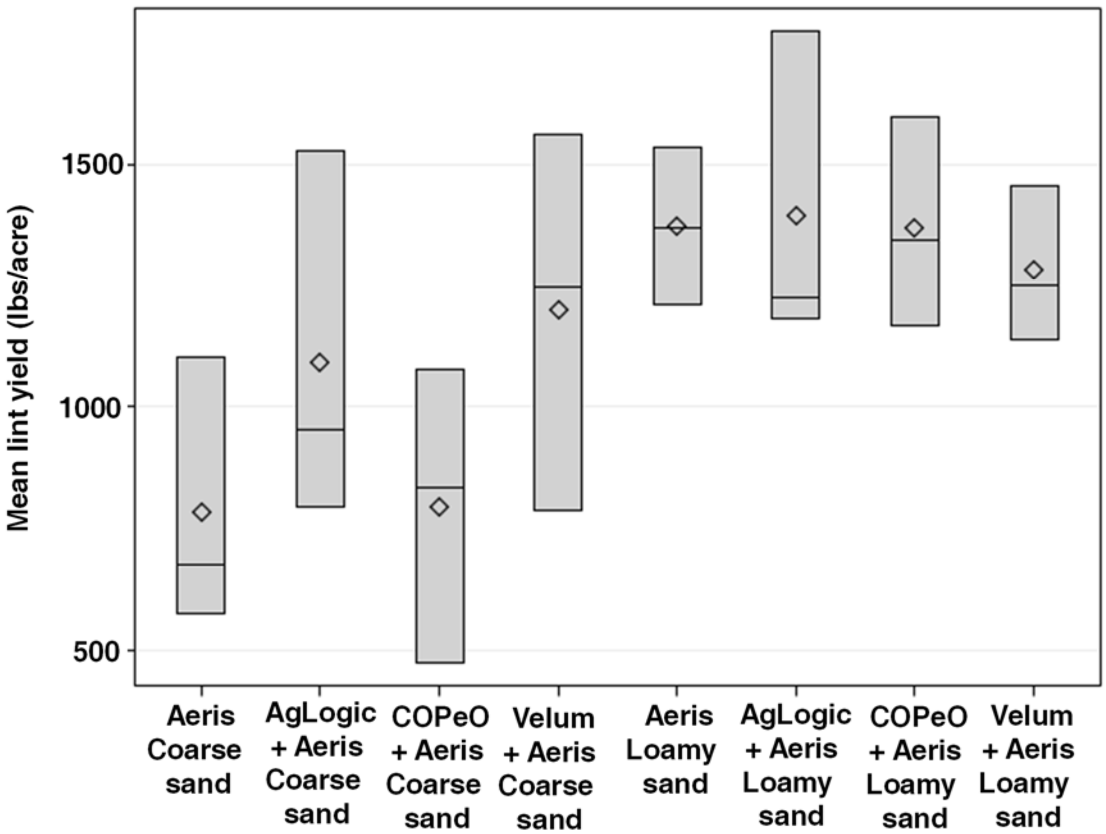

Figure 6. Mean lint yield among insecticide/nematicide treatments and soil textures determined from hand-picked harvest at sample points in designated 10ft or row sample sites. Lint calculations were based on 41% turnout. Boxes represent 50% quartile; diamonds within the box depict means and lines indicate median.– 2016, Manila, AR.

Fiber quality assessments (HVI) from 40 boll hand-picked samples indicated significant differences in several fiber quality parameters associated with soil texture; however, no differences nor interactions were associated with at planting nematicide / insecticide treatments (Table 6). Mean boll weights from plants in coarse sand were significantly lower than from loamy sand. There also were significant differences in micronaire and elongation associated with soil texture. Micronaire readings were in the base range among all treatments.

Table 6. Fiber quality assessments (HVI[a]) for 40-boll collections in cultivar, irrigation, and tillage treatments.

Soil texture[b]	Boll weight (g)	Micronaire	Length	Uniformity	Strength	Elongation
Coarse sand	4.4	4.40	1.22	84.50	33.50	6.50
Loamy sand	5.0	4.70	1.22	85.10	33.40	6.65
P>F	*0.05*	*0.04*	*0.38*	*0.20*	*0.91*	*0.19*
LSD_{05}	*0.53*	*0.29*				*0.2*

[a] HVI assessments made at the Fiber and Biopolymer Research Institute, Texas Tech University, Lubbock, TX.

[b] No significant at-planting treatment or treatment*texture interactions.

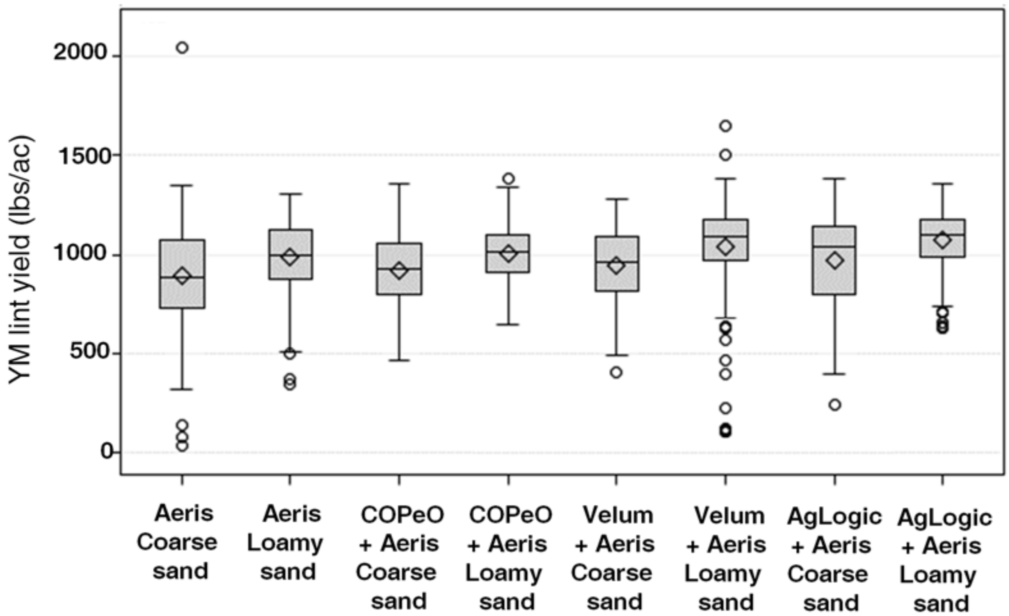

Figure 7. Mean lint yield among insecticide/nematicide treatments and soil textures determined from yield monitor data. Boxes represent 50% quartile; diamonds within the box depict means, and the line is the median value.—2016, Manila, AR.

Discussion

Negative impacts from feeding injury by pests depends on extent of injury as well as plant tolerance and/or compensation capacity. Many factors can affect extent of tolerance to pests and compensation capacity including management choices for cultivar selection, date of planting, plant stand density, timing and adequacy of fertilizer and irrigation applications, and correct use of plant growth regulators. Susceptible plants are most likely to exhibit greatest potential benefit from use of protectants.

In this study, a positive early season plant response was observed to the in-furrow applied broad-spectrum protectants, AgLogic and Velum Total in field areas with the most vulnerable plants. These at-planting protectants provided both insecticidal and nematicidal activity. The active ingredient in CoPeO and one of the active ingredients in Velum Total is fluopyram which belongs to the succinate dehydrogenase inhibitor (SDHI) fungicide chemical class. According to the Velum Total label, fluopyram provides suppression of nematodes by contact activity in the soil, but also has been shown to suppress certain fungal disease causing pathogens through root uptake and xylem systemic movement to plant foliage. Fungicide activity has been observed for *Fusarium* spp, and the causal organism for target spot, *Corenespora cassiicola*. Imidacloprid provides suppression of insects on foliage through root uptake and xylem systemic movement to plant foliage. Aldicarb has a long history of use in Midsouth cotton and has been associated with broad spectrum suppression and control of a range of nematodes and insects. Aldicarb also has been reported to have a positive plant growth regulator effect, sometimes referred to as the carbamate kick, improving early season plant vigor.

Although plant response to these products was observed in early season, by the end of the season, no significant maturity, yield, or fiber improvements were noted. We did measure a strong relationship of yield and soil EC. Within field spatial variability was identified and measured. There were significant differences in plant development, lint yield, and fiber quality depending on soil texture.

Ortiz et al. (2012) suggested a site-specific approach to nematode management based on soil textures if nematode population densities were above action thresholds. In our 2016 trial, both nematode and insect pest densities were at moderately low levels. When pest levels present sufficient risk for economic damage, we believe that use of site-specific applications of protectants could be an effective preventative tactic to manage an array of seedling pests in cotton. For example, with insect pests such as thrips, use of at-planting protectants in identified field areas with less productive soils and plants with low yield potential (i.e. low compensation capacity), is more likely to provide measurable benefits in low to moderate infestations than use in field areas with plants with higher carrying capacity and potential to recover from injury.

Benefits from site-specific management should include reduced production costs, improved efficiency, and lower environmental risks. Each are essential steps in improving cotton sustainability. The on-farm practicality of a pest management program with site-specific use of at-planting protectants will depend on spatial management capacity of the farm, including adequate equipment and technical expertise, extent of within field variability, and the total application costs for protectants. We plan to repeat this study in 2017 with additional treatments and expanded geostatistical analysis and economic evaluations.

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References

Bourland, F.M., D.M. Oosterhuis, N.P. Tugwell, M.J. Cochran and D.M. Danforth. 2008. Interpretation of crop growth patterns generated by COTMAN. *In:* D.M. Oosterhuis and F.M. Bourland (Eds). COTMAN Crop Management System. U. of Ark Agric. Exp. Sta., Fayetteville, AR.

Doerge, T.A. 1999. Management zone concepts. SSMG-2. *In:* Site-specific management guidelines. Potash & Phosphate Institute. Atlanta, GA.

Hearn, A.B. and G.D. da Roza. 1985. A simple model for crop management applications for cotton (Gossypium hirsutum L.). Field Crops Res., 12: 49-69.

Mueller, J, T. Kirkpatrick, C. Overstreet, S. Koenning, B. Kemeratit, and B. Nichols. 2012. Managing nematodes in cotton-based cropping systems. Cotton Incorporated. www.cottoninc.com/fiber/AgriculturalDisciplines/Nematology/2012-Managing-Nematodes/2012-Managing-Nematodes.pdf. Accessed 26 December 2016.

Overstreet, C., Wolcott, M. C., Burris, E., Padgett, G. B., Cook, D. R., and Sullivan, D. L. 2005. The response of Telone against the southern root-knot nematode in cotton across soil electrical conductivity zones. Journal of Nematology 37:387.

Oosterhuis D.M. and F.M. Bourland. 2008. (eds.) COTMAN Crop Management System, University of Arkansas Agricultural Experiment Station, Fayetteville, AR. pp. 107.

Ortiz, B.V., C. Perry, D. Sullivan, P. Lu, R. Kemerait, R. F. Davis, A. Smith, G. Vellidis, R. Nichols. 2012. Variable rate application of nematicides on cotton fields: A promising site-specific management strategy. J. Nematology 44:31-39.

Sadras, V.O. and G. Felton. 2010. Mechanisms of cotton resistance to arthropod herbivory. pp. 213-228 In: J.McD. Stewart, D.M. Oosterhuis, J.J. Heitholt, and J.R. Mauney. (Eds.), Physiology of Cotton. Springer, N.Y.

Teague, T.G. 2016. Plant-insect interactions and cotton development. Pp. 27-65 *In:* J. Snider and D.M. Oosterhuis (Eds.), Linking Physiology to Management. Cotton Foundation Reference Book Series Number Nine. The Cotton Foundation. Cordova, TN, USA.

Wheeler, T. A., Kaufman, H. W., Baugh, B., Kidd, P., Schuster, G., and Siders, K. 1999. Comparison of variable and single-rate applications of Aldicard on cotton yield in fields infested with *Meloidogyne incognita*. Supplement of the Journal of Nematology 31:700–708.

Wolcott, M. C. 2007. Cotton yield response to residual effects of Telone Fumigant. *In:* S. Boyd and M. Huffman (Eds.) Proc. of the 2007 Beltwide Cotton Conferences, National Cotton Council, Memphis, TN.