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PREDICTING NEMATODE HOTSPOTS USING SOIL EC DATA

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Abstract

The root knot nematode (RKN), *Meloidogyne incognita*, is a damaging pest that causes major losses to the cotton industry annually. In Georgia, 60-70 percent of cotton fields are infested with this pest. Because application of nematicides is expensive and environmentally controversial, farmers put off applying the necessary chemicals. But RKN are not evenly distributed across fields. RKN populations have been shown to be higher in areas with higher sand content. Soil electrical conductivity (EC) can be used to characterize soil differences including soil texture. In 2005, a study was begun to determine if data from a Veris 3100 soil EC sensor could be used to identify nematode hot spots in cotton fields in south Georgia. First year results were mixed. EC data compared reasonably well with lab texture results, but did not correlate well with nematode counts in the fields. Additional analysis of collected data as well as additional data may be required before hot spots can be reliably identified.

Introduction

Cotton nematodes are a persistent and damaging pest causing major losses annually to the cotton industry (Starr et al., 1993). Nematodes are microscopic pathogens, but sometimes can reach 10 feet in length, having the appearance of a worm. These pathogens live in the soil and feed on the root of plant. The major species are root-knot, reniform, lance, and sting nematodes. Although all these species are common in the U.S. Cotton Belt, only *Meloidogyne incognita* reduce cotton yield (Wheeler and Kaufman, 2003).

The Southeastern U.S. suffers high levels of root knot nematodes in cotton. In Georgia, RKN are the most important plant–parasitic nematode because of their widespread distribution. It has been suggested that 60 to 70 percent of Georgia's cotton fields are infested with this damaging nematode species (University of Georgia, 2005). The root-knot nematode (RKN) (*Meloidogyne incognita*) produces knots or galls on roots that look like knots in a rope.

Virtually all cotton cultivars on the market are susceptible to *Meloidogyne incognita*. Davis and May (2004, 2005) found that yield suppression (kg lint/ha) ranged from 18% to 47% in 2002 and 9% to 36% in 2003. The percentage yield loss differed among cultivars such that cultivars with higher yield potentials also had greater percent yield loss to *Meloidogyne incognita*. They noted that it appears unlikely that cotton cultivar selection for tolerance to *Meloidogyne incognita* can be used to minimize yield losses. Other studies have indicated yield losses can range from 10% to 75%, depending on soil properties and weather conditions.

Application of nematicides is both expensive and environmentally controversial. Georgia experts estimate that a grower spends $36/acre on pesticides plus sampling fees (Kemerait, 2005). Because of the expense, farmers tend to put off nematicide applications until they perceive that the economic damage they sustain from RKN outweighs application costs. Then, farmers generally apply nematicides over the whole field.

Yet, studies have shown that nematodes are not evenly distributed in fields and that they tend to have higher populations in sandy areas of a field (Gazaway and McLean, 2003). Precision Agriculture tools offer a promising alternative to field-scale sampling and blanket applications of pesticides. By developing creative uses of currently available tools, we anticipate developing knowledge of nematode-prone areas in fields which would allow farmers to greatly reduce sampling and pesticide costs while improving profitability and maintaining environmental quality.

Soil electrical conductivity (EC) measured using electromagnetic induction and electrical resistivity has been one of the most reliable techniques to characterize field variability for Precision Ag purposes (Corwin et al., 2003). Within-field soil differences and spatial variability of crop yield have been identified used soil EC measurements (Kitchen et al., 1999; Sudduth et al., 1998). However, most research on the use of EC data in Precision Ag has been in the MidWest and Plains states.

This paper reports some of the results from the first year of a multi-year study to determine if a commercially-available soil EC mapping system can be used to predict nematode hotspots in south Georgia cotton fields.

Materials and Methods

Study Sites

Six farmer-owned cotton fields in or adjacent to Tift County, Georgia, were identified. These fields were selected on the basis of size (relatively small), close proximity to our research campus, and potential for nematode infestation. The fields were comprised of mostly Tifton loamy sand and ranged in topography from relatively flat to very rolling. The fields are further described in Tables 1 and 2.

Table 1. Fields involved in the 2005 cotton nematode study.

Field	Size (ac)	Crop/Variety	Plant Date	Harvest Date
BJ	52.6	Cotton / DP555	May 20	November 7-9
BP	22.2	Cotton / DP555	May 1	October 19
CG	40.9	Cotton / DP555	May 11	October 18-19
FR	6.3	Cotton / DP555	May 10	October 11
PG	21.9	Cotton / DP555	May 18	October 21, 24
RB	21.1	Cotton / DP555	May 7	October 31

Data Collection

Soil EC

Apparent soil EC across each field was measured with a Veris 3100 EC sensor (Veris Technologies, Salina, Kansas). This sensor (Fig. 1) uses a series of six disks mounted to a toolbar which is pulled across a field with the disks contacting the soil. The disks act as electrodes and the system records soil EC readings from two different depths every second. One pair of disk-electrodes induces current into the soil and the change in voltage is measured across the other two pairs of disk-electrodes resulting in simultaneous EC measurements for the top 1 ft (30 cm) of soil (“shallow”) and the top 3 ft (90 cm) of soil (“deep”).

A Trimble AgGPS 114 WAAS GPS receiver was connected to the Veris controller to provide position data for each EC reading. To maintain straight swaths across the fields, an Ag Leader EZ Guide Plus light bar was used and swaths were run approximately 25 ft apart. An average of 5000 data points was collected in each field. EC data was collected in the fields between late January and April of 2005.

Figure 1. Veris 3100 soil EC sensor being pulled through soil. Tractor has RTK-GPS mounted for topo mapping.

Topography / Elevation

Topographic data was collected during EC data collection by using an RTK GPS system. A Trimble AgGPS 214 was mounted on the tractor pulling the Veris 3100 sensor (Fig. 1). A Trimble base station was deployed to provide correction data to the tractor GPS. Latitude, longitude, and elevation data was collected at 1 Hz.

Soil Cores

To verify the Veris EC sensor data could be used to indicate soil texture, a number of soil cores were extracted from each field for lab analysis. Once Veris data was obtained and mapped, soil zones (zones with similar EC values) were delineated. Sampling points were established pseudo-randomly across the fields, with several sampling points per soil zone. Some sampling points were intentionally established across soil zone transitions. Figure 2 shows the BJ field with soil zones and soil core sampling points marked.

We used a Giddings 2-5/8 in diameter by 36 in stainless steel standard solid soil tube fitted with a standard taper stainless steel tube bit. We inserted 2-3/8 in diameter PETG plastic liner tubes inside the soil tube. A special collar was custom installed at the top of the soil tube so that a gas-powered jack hammer could drive the soil tube into the soil. The soil tube was driven into the soil to a depth of approximately 36 in or to a point that the jack hammer could not push the core deeper. A custom-made lift implement was built to allow cores to be pulled from the soil with a tractor 3-point hitch. Once removed from the soil and from the soil tube, individual undisturbed soil cores were capped using air-tight plastic caps.

In the lab, half of the plastic soil liner tube was cut away exposing the core. The depth to clay layer for each core was determined and then each was photographed. Each core was subdivided into four subsamples – 0-15 cm, 15-30 cm, 30-60 cm, and 60-90 cm. The soil in each subsample was thoroughly mixed and then a sample of the mixed soil was removed and placed in a plastic storage bag.

A complete particle size distribution for each core subsample was determined using the basic hydrometer method. Particle size data were grouped into sand, silt, and clay according to the USDA standard. The lab results for the 0-15 cm and 15-30 cm subsamples were averaged to give the 0-30 cm texture values. The lab results for the 0-15, 15-30, 30-60, and 60-0 were used in a weighted average to give the 0-90 cm texture values.

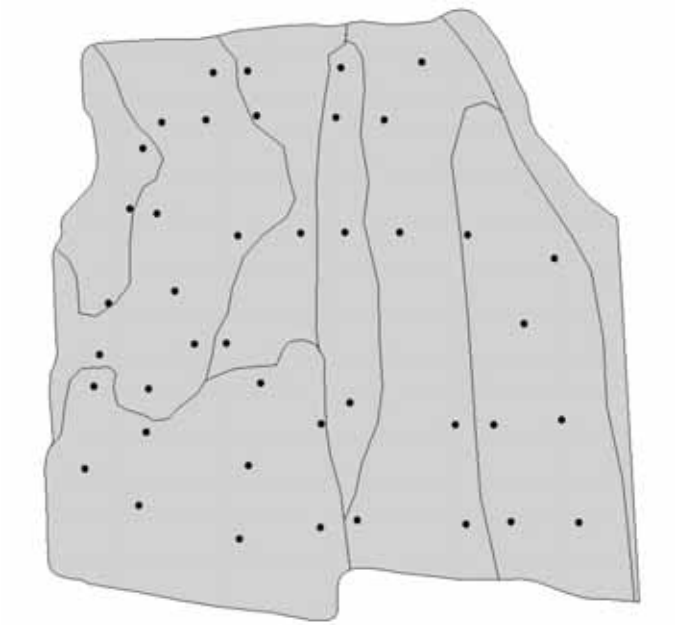

Figure 2. Soil zones and soil core sampling points for BJ field.

Nematode Counts

To collect soil samples for nematode counts, a 0.5 ac uniform grid was established for each field (Fig. 3). We used this grid sampling pattern to aid in estimating the spatial-temporal nematode population. Nematode samples were collected four times during the growing season: June (planting), July, August, and October/November (harvest). The soil sampling strategy was designed in that way because the nematode populations are usually low in spring, increase through the growing season and reach peak densities near harvest.

At each grid sampling location, 8 individual subsamples were collected within a 5 ft radius from the grid point. Soil probes of 1.18 in in diameter were used to extract the soil cores. The probe was inserted 6-12 in deep into the soil. The 8 subsamples were combined into one composite sample. The soil samples were placed into plastic bags and kept cool before they were sent to the laboratory. A Trimble AgGPS 114 WAAS GPS was used to georeference the soil/nematode sampling location.

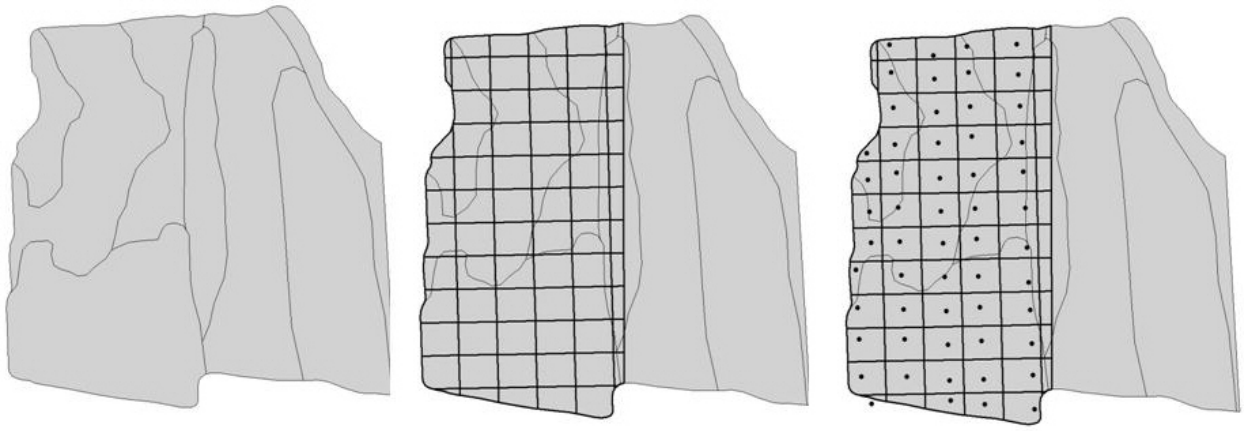

Figure 3. Sampling grid (1/2 ac) and sampling points for BJ field for nematode count study.

Yield

An Ag Leader cotton yield monitoring system fitted on our John Deere 9965 four-row cotton picker was used to harvest the BJ, FR, PG, and RB fields. Our picker had yield sensors on rows 1 and 3 only. A Trimble AgGPS 132 provided position information for the yield monitor.

A farmer-owned 9965 picker also equipped with an Ag Leader cotton yield monitor harvested the CG field. This picker had all 4 rows with sensors and used an Ag Leader 1000 WAAS GPS for position information. A farmer-owned John Deere 9986 six-row picker was fitted with a new Deere cotton yield monitor system and was used to harvest the BP field. This picker had all six rows equipped with the Deere cotton flow sensors and had a Deere StarFire DGPS receiver for position data.

Results

Laboratory Data

The results from the 2005 field data collection are summarized in Tables 2 and 3. Table 2 provides the soil texture data derived from the soil core lab analyses. The sand components in both the 0-30 cm and 0-90 cm depths have low CV values indicating little variability in that component across the fields. This suggests that our sand analysis was possibly using too broad a range for particle size for this classification. Conversely, the clay component in the analysis had much higher variability, possibly suggesting a classification range that was too narrow.

Table 3 provides the nematode count (RKN) from the third sampling date, EC data from the Veris sensor, and yield data. Yields averaged 2 bales in only two of the fields (BP and CG). As expected, the nematode counts were highly variable. EC values for both depths were also highly variable. However, the soils in this study are quite sandy as the mean sand texture values indicate.

Table 2. Soil texture lab results. SD = standard deviation; CV = coefficient of variability in percent.

		Field					
		BJ	**BP**	**CG**	**FR**	**PG**	**RB**
Sand % (0-30 cm)	min	73.79	74.58	71.91	82.75	72.71	72.41
	max	93.74	91.94	94.57	91.37	91.92	91.43
	mean	87.59	84.84	90.21	88.43	84.99	84.83
	SD	5.53	3.88	4.44	2.57	5.45	4.86
	CV	6.31	4.57	4.92	2.91	6.41	5.73
Clay % (0-30 cm)	min	1.04	-0.32	1.25	1.95	1.35	2.86
	max	20.13	15.57	19.27	9.16	17.96	20.58
	mean	6.45	4.03	4.59	3.95	6.67	7.80
	SD	5.20	2.72	3.64	2.19	5.01	4.73
	CV	80.63	67.47	79.34	55.36	75.15	60.64
Sand % (0-90 cm)	min	53.77	70.23	60.07	71.91	51.44	44.48
	max	91.66	90.90	92.04	84.95	91.34	86.51
	mean	76.38	83.93	82.76	78.88	76.50	75.46
	SD	9.61	3.44	9.09	4.41	10.30	8.87
	CV	12.58	4.10	10.98	5.59	13.46	11.76
Clay % (0-90 cm)	min	1.88	0.05	0.85	7.89	0.75	5.17
	max	33.37	14.22	17.29	20.60	35.14	26.40
	mean	14.87	5.11	7.86	13.48	15.42	16.07
	SD	7.86	2.45	4.25	4.38	10.43	6.65

	CV	52.88	47.90	54.08	32.52	67.66	41.36
No. Samples		42	41	40	10	25	28

Table 3. Nematode, soil EC, and yield results.

		Field					
		BJ	**BP**	**CG**	**FR**	**PG**	**RB**
RKN (8/31)	min	0	88	0	0	2	16
	max	580	1516	256	988	2820	2832
EC Shallow (mS/m)	min	0.00	0.00	0.00	0.11	0.13	0.72
	max	4.50	1.51	5.01	1.30	7.19	7.97
	mean	1.13	0.39	0.95	0.48	2.42	2.44
	SD	0.80	0.34	1.24	0.35	1.92	1.76
	CV	70.18	86.77	130.49	73.38	79.39	72.00
EC Deep (mS/m)	min	0.40	0.07	0.21	0.37	0.42	1.81
	max	6.67	2.52	8.17	3.78	11.44	12.32
	mean	2.09	0.79	2.27	1.87	4.62	4.90
	SD	1.17	0.41	2.06	1.18	3.15	2.32
	CV	56.00	51.60	90.91	62.99	68.10	47.41
Yield (lb/ac) Lint	min	148.61	255.71	219.72	36.29	231.37	255.37
	max	1165.82	1530.94	1513.45	1027.30	1284.22	1301.28
	mean	787.49	1075.49	1057.87	603.56	745.27	843.54
	SD	304.29	289.64	243.53	348.58	216.78	233.50
	CV	38.64	26.93	23.02	57.75	29.09	27.68
No. Samples		56	44	40	17	48	46

To compare Veris EC measurements to the lab texture results, a GIS analysis was conducted. The Veris EC data (shallow and deep), Yield data, and elevation data were each Kriged and smoothed to a continuous surface. For each soil core extraction location, EC, Yield, and elevation were determined by averaging the data within a 12 ft buffer around each extraction location point. Table 4 provides the Pearson's Correlation Coefficient (R) for comparisons between sand and clay texture measurements and EC data as well as for comparisons between sand/clay and yield and between EC and yield. The results indicate a moderate to good correlation between lab texture results and Veris EC values (R values between 0.35 and 0.95). Yield was much less correlated with texture results (with the exception of FR field). EC and Yield were also less correlated (again with the exception of the RF field).

To compare nematode count data to Veris EC data, a similar process was followed for each nematode sampling location. For each nematode sampling point, Veris EC data (shallow and deep), Yield data, and elevation data were determined by averaging the data within a 12 ft buffer around each nematode sampling point. Table 5 provides the Pearson's Correlation Coefficient (R) for comparisons between EC data and nematode count (RKN) as well as for EC data and Yield and Elevation and nematode count. The results indicate only a slight correlation between EC data and nematode count (R values between 0 and 0.37) but a higher correlation between EC data and yield. The effect of nematode count on yield had little correlation as did elevation effect on nematode count.

Table 4. Correlation values for data associated with each soil core sampling point.

	Field					
	BJ	**BP**	**CG**	**FR**	**PG**	**RB**
Comparison (X vs. Y)	**R Values**					
Sand % (0-30) vs. EC Shallow	0.67	0.58	0.42	0.81	0.79	0.88
Clay % (0-30) vs. EC Shallow	0.64	0.77	0.42	0.87	0.81	0.95
Sand % (0-90) vs. EC Deep	0.90	0.52	0.35	0.86	0.88	0.88

Clay % (0-90) vs. EC Deep	0.61	0.69	0.69	0.89	0.88	0.82
Sand % (0-30) vs. Yield	0.17	0.14	0.22	0.68	0.24	0.17
Clay % (0-30) vs. Yield	0.10	0.14	0.22	0.75	0.24	0.17
Sand % (0-90) vs. Yield	0.10	0.28	0.14	0.79	0.32	0.10
Clay % (0-90) vs. Yield	0.35	0.32	0.26	0.79	0.30	0.00
EC Shallow vs Yield	0.32	0.00	0.26	0.92	0.45	0.20
EC Deep vs. Yield	0.30	0.17	0.33	0.95	0.46	0.14

Table 5. Correlation values for data associated with each nematode sampling point.

	Field					
	BJ	**BP**	**CG**	**FR**	**PG**	**RB**
Comparison (X vs. Y)	**R Values**					
EC Shallow vs. RKN (8/31)	0.00	0.00	0.10	0.32	0.32	0.33
EC Deep vs. RKN (8/31)	0.00	0.00	0.22	0.32	0.24	0.37
EC Shallow vs Yield	0.44	0.28	0.00	0.79	0.52	0.46
EC Deep vs. Yield	0.53	0.26	0.28	0.88	0.62	0.30
RKN (8/31) vs. Yield	0.32	0.14	0.33	0.00	0.14	0.24
Elevation vs. RKN (8/31)	0.00	0.00	0.20	0.14	0.17	0.41

Spatial Data

The results of the field data collection phase resulted in a wealth of spatial data. Figure 4 shows the shallow and deep Veris EC data from one of the fields in the 2005 study. The lower the EC value indicates higher sand content in the soil profile (0-30 cm or 0-90 cm). The maps in Figure 4 represent Kriged/smoothed data derived from the original point Veris EC data.

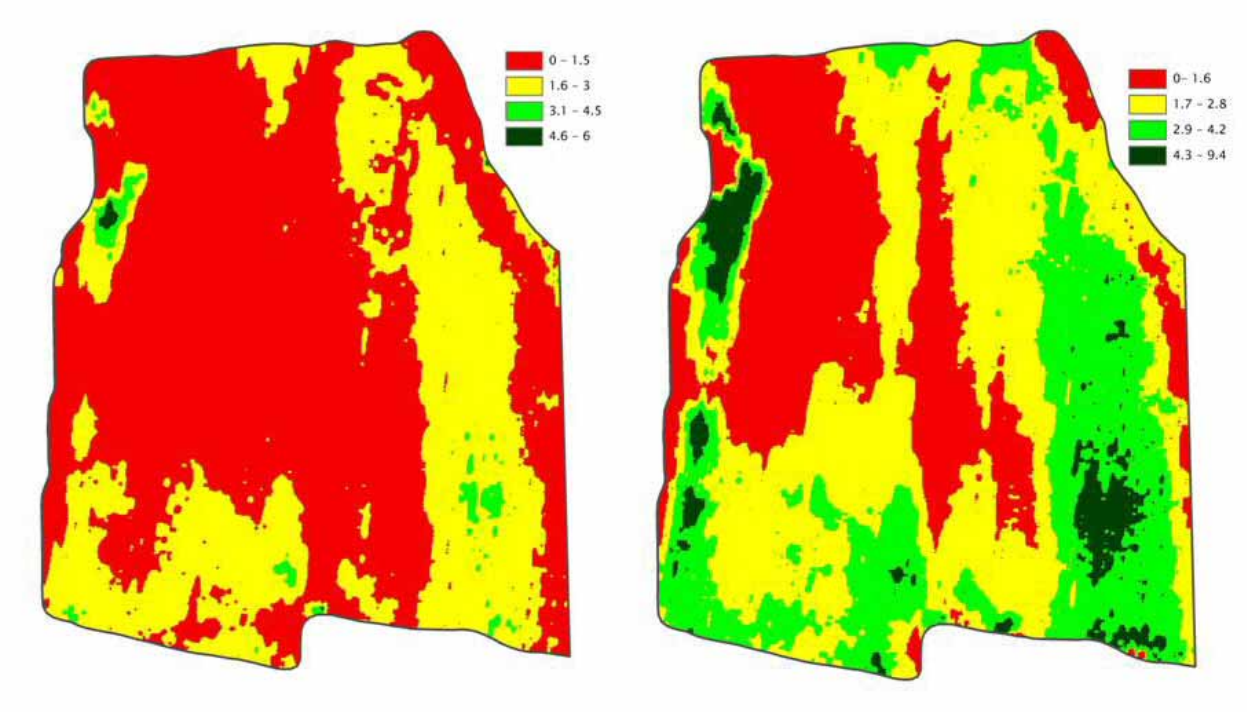

Figure 4. Shallow (left) and deep (right) Veris EC data. Lower values (mS/m) indicate higher sand content.

Figure 5 represents the seasonal progression of nematode counts across one of the fields in the study. The figure on the left indicates no incidence of nematode infestation on that sampling date. The middle figure indicates nematode counts are rising in some spots. The figure on the right indicates that almost all sampling points show nematodes. This pattern of progression was common to all six fields.

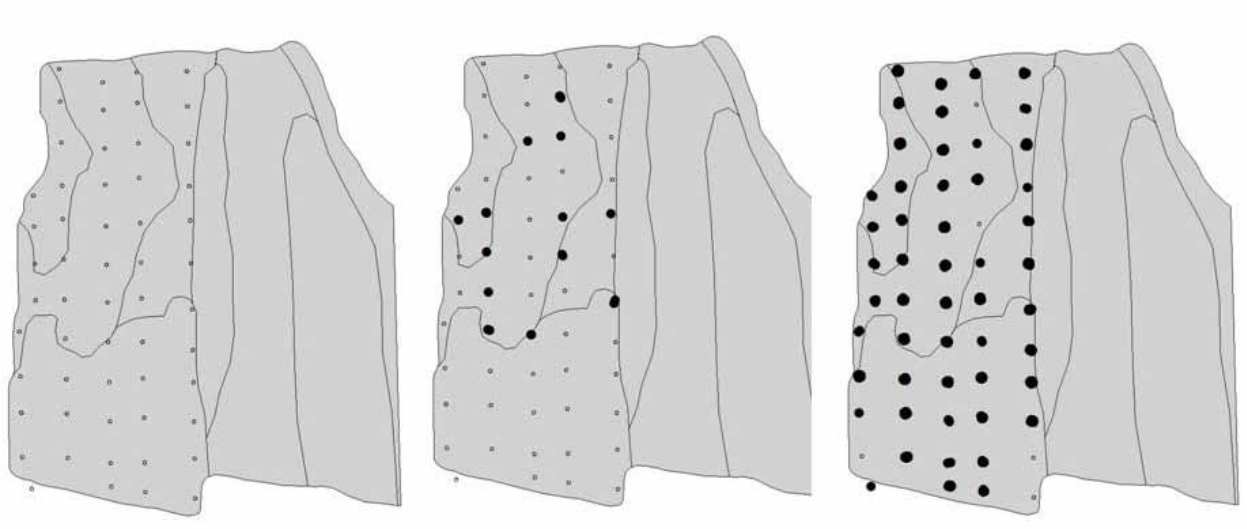

Figure 5. Progression of nematode infestations across a field during the growing season. Image on left indicates no infestation. Each additional solid circle added represents a nematode count of 10 or more.

Figure 6 shows the elevation data across the field as well as the resulting yield map. Again, the maps in Figure 6 represent Kriged/smoothed data derived from the original point topo data and yield data.

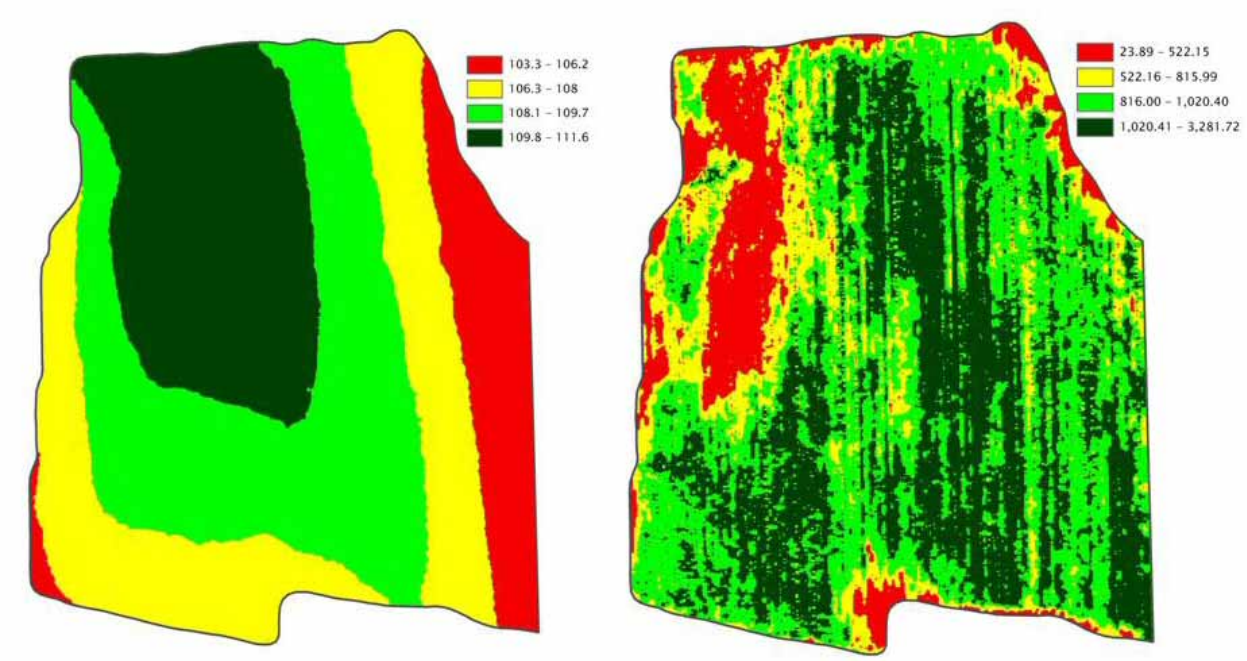

Figure 6. Elevation/topo data (left) and yield data (right) for the BJ field. Elevation is in meters and yield is in lb/ac lint.

Conclusions

First-year results from this project were mixed. Soil EC data from the Veris 3100 EC sensor proved to be useful for creating soil zones in the six fields involved in this study. Correlation coefficients indicated that shallow (0-30 cm) and deep (0-90 cm) EC data compared reasonably well with lab texture results. The variability in the EC data suggests that the Veris EC sensor was more sensitive to changing texture conditions than the particle size analysis was capable of quantifying. Therefore, the sand fraction in conjunction with texture analysis may be necessary to better evaluate the ability of the Veris EC data to serve as a surrogate for soil texture.

Though the Veris EC data correlated reasonably well with texture, it did not correlate well with nematode counts in the fields (R values between 0 and 0.37). Thus at this stage, we do not believe that we can reliably predict nematode hot spots with soil EC data alone. Further analysis of additional 2005 data (remote sensing / hyperspectral data, pH, and plant height) may improve our ability to predict nematode hot spots.

During the second year of this project, in addition to the data collected in 2005, we anticipate collecting/measuring additional data including soil (sand) fraction, soil nutrients, and moisture content.

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