PRECISION CONTROL OF NEMATODES IN ARIZONA CROPPING SYSTEMS

E.R. Norton
T.B. Hatch
Safford Ag Center
Safford, AZ
The University of Arizona
M.A. McClure
School of Plant Sciences
Tucson, AZ
The University of Arizona
P. Andrade-Sanchez
Department of Agricultural and Biosystems Engineering
Maricopa, AZ
The University of Arizona

Abstract

This paper summarizes work completed over the past five years evaluating the effectiveness of precision placement of the nematicide Telone II for control of nematodes in Arizona cropping systems. A high degree of correlation between nematode population distributions and soil texture has allowed for the implementation of precision placement of Telone II in areas where nematode distribution, and thus damage to cotton, is spatially variable. This work was completed on grower-cooperator fields across Arizona in a wide variety of environments. Techniques involved in this work included directed spatial sampling for nematodes, soil apparent electrical conductivity (EC_a) surveys with Veris and EM38 sensors, and yield mapping analysis. All techniques were used in an effort to develop accurate prescription application maps that could then be used to guide the variable placement of Telone II for effective control of southern Root-knot Nematode (*Meloidogyne incognita*). Results have demonstrated effective use of these technologies, under certain conditions, to enhance both economic and environmental efficiencies with respect to nematode control. Yield response to Telone II application was positive in nearly all locations and across all soil texture zones and ranged from 0% to over 120% increase in yield over the control. The highest level of response was consistently observed in zone 1 (coarsest soil texture). However, return on investment was not always positive. In fields with a high degree of soil texture variability, zone 1 consistently produced a positive economic return while application of Telone II in finer soil texture zones resulted in loss of income. Validation of these results will continue into the 2011 season on both cotton and corn.

Introduction

Nematode Damage

Many of the pests that are of economic importance in Arizona cropping systems are readily identifiable through scouting of fields. However, one of the most damaging pests in our production systems that often go unseen is the plant parasitic nematode. There are several plant parasitic nematodes in Arizona but the most widespread, and the one of most economic significance is the southern Root-knot Nematode (RKN – *Meloidogyne incognita*). Across the cotton producing regions of the US, nematodes are responsible for as much as a 5% reduction in lint yield (Blasingame, 2009). Similar reductions in yield have been observed in Arizona production systems. Significant positive yield response has been observed in several crops in Arizona with the application of Telone II as a nematicide (Husman et al., 1996). In many areas of the state the application of 5 gallons per acre (gpa) of Telone II has become a standard production practice to maintain cotton yield in nematode infested fields.

Nematode Distribution

A significant portion of the soils across Arizona that are utilized for growing crops are stream and river deposited alluvial soils containing the remnants of old streambeds and washes. This type of soil development and deposition is characteristically variable in edaphic factors such as soil texture. A typical 70-acre field may have as many as five or six distinct soil classifications with a high degree of soil texture variability. These edaphic factors have been shown to affect both the population dynamic and the distribution of nematodes (McSorley, 1988). Soil texture can influence the population distribution both horizontally and vertically within the soil and has been suggested as a useful predictor of areas within a field of high potential for crop damage from nematodes (Noe and Barker, 1985). Researchers have also observed strong correlations between RKN populations and the percentages of finer soil particles (silt and clay). Koenning and colleagues (1996) demonstrated a strong negative correlation between the silt and clay content of soil and the population of southern RKN. Detailed sampling of a specific field in the upper Gila River valley of Safford, AZ also demonstrated a strong relationship between soil texture and southern RKN populations (Figure 1). This relationship of soil texture and RKN population has been exploited to increase the efficiency of nematode control in fields with high levels of soil texture variability (Monfort, et.al., 2007; Starr, et.al., 2007).

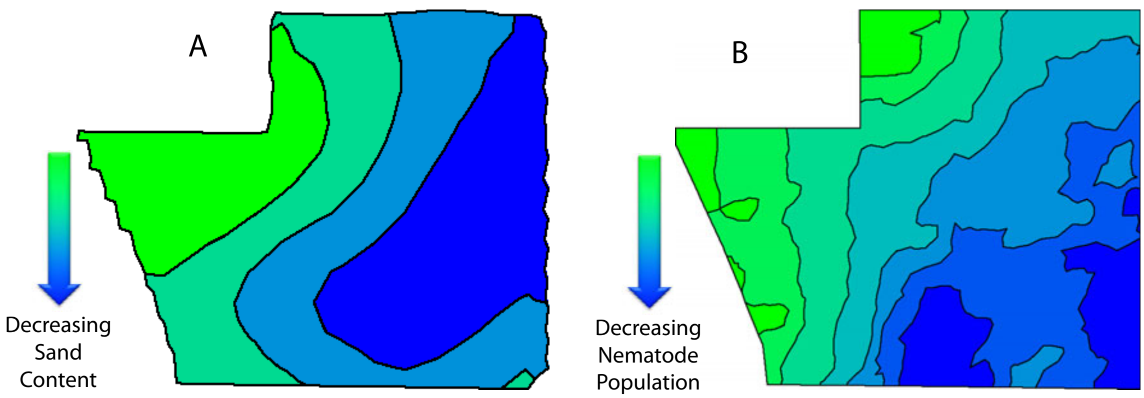

Figure 1. The distribution of Root-knot nematode is typically closely related to soil texture. The soil texture map (A) derived from a Veris 3100 EC_a survey illustrates the changes in soil texture of this 34 acre field from a soil dominated by sand (light green) to a soil dominated by a clay loam (dark blue). The same field was sampled on a 50 ft x 50 ft square grid pattern and analyzed for RKN populations. The data is plotted in the contour map (B) illustrating the change in RKN levels from high populations (light green) to nearly non-existent levels of RKN (dark blue) which is highly correlated to the sand content (A).

Rationale and Goal

Utilizing this relationship and the high soil variability observed in many Arizona soils, our goal was to use the emerging technologies of precision agriculture to improve the efficiency with which nematodes are controlled in our agricultural production system. The costs associated with the control of nematodes may often be prohibitive if applied over an entire field. Observational data suggests that the entire field is often not in need of a nematicide application. The ability to target and apply a nematicide to specific areas of a field that are predicted to have high potential for crop damage while avoiding application on areas of the field with a low potential for crop damage allows the grower to greatly enhance the efficiency of nematode control thereby improving profitability and reducing the amount of nematicide released into the environment.

Materials and Methods

Several field trials were conducted over the course of the last four years (2007-2010) as a result of the initial positive response in a 2006 evaluation designed to target nematode levels based upon the previous year's yield map. Telone II was applied in the low yielding areas of the field and resulted in significant yield increases and improvement of yield uniformity. Beginning in 2007 a series of field trials were constructed to evaluate the precision placement of

Telone II based upon a more detailed characterization of the field of interest. Each evaluation was constructed in a similar fashion each year and the data collected was uniform across all site years.

Site Selection and Characterization

Each field site was selected based upon grower input, USDA soil survey maps, and baseline levels of nematode populations. All field sites reside in Arizona and include Safford, AZ, Bonita, AZ, Coolidge, AZ, and Buckeye, AZ (Table 1). Once a field was identified for the trial, a survey was conducted utilizing the Veris 3100 soil EC_a mapping technology. These data were used to provide a base map of soil texture variability which was used to develop the prescription application map. The data was imported into the software package Spatial Management System (SMS AgLeader Technology, 2202 South River Side Drive, Ames, IA, 50010, USA) software to analyze the data. Utilizing the "Equal Points" mapping mode, four soil texture zones were delineated with zone 1 containing the coarsest texture soil and zone 4 the finest texture. Figure 2A illustrates a typical Veris survey for the 2009 Bonita, AZ location. This map was then used to develop the prescription map that was subsequently used for the Telone II application. The prescription map was set-up to apply Telone II at a specific rate to zones 1 and 2 and applying no Telone II to zones 3 and 4. Figure 2B shows the corresponding prescription map for the 2009 Bonita, AZ location.

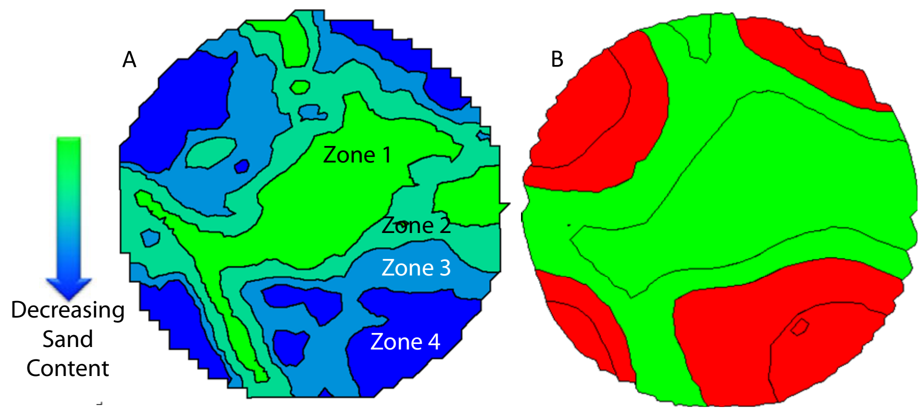

Figure 2. Soil texture management zones delineated by the Veris 3100 soil EC_a mapper (A) with the coarsest texture soils in zone one and progressing to finer texture soils in zone four along with the corresponding prescription application map (B) where green is treated at 5 gpa and red is left untreated for the Bonita location conducted in 2009.

Application of Nematicide (Telone II)

Application of Telone II was made each year along a similar pattern of following the prescription in a significant portion of the field, while incorporating a minimum of three 'verification strips' randomly placed across the trial area. The verification strips consisted of uniformly-treated (5 gallons per acre (gpa)) and untreated strips (0 gpa) extending the full-length of the trial field traversing all four soil texture zones. Each strip was from 18 to 24 rows wide and allowed for evaluation of crop response (yield) to the Telone II application within each soil texture zone as delineated by the Veris survey. All applications of Telone II were made utilizing a 6-row injection implement (AZ Drip Systems, Coolidge, AZ) equipped with a Raven positive displacement piston injection pump connected to a Raven Viper precision application management system and an Invicta 115 Differential correction GPS antenna/receiver. All Telone II application rates were either 0 gpa in the untreated areas of the prescription maps or 5 gpa in the treated areas, except for the 2010 Buckeye location where treatments consisted of 0 gpa (very limited acreage), 3 gpa, and 5 gpa. The rate change in Buckeye was due to the high nematode population densities where yield could be significantly

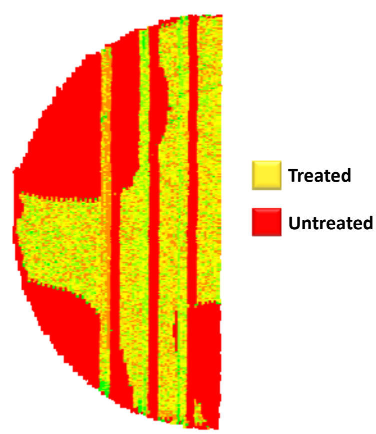

Figure 3. Map indicating treated and untreated areas at the Bonita, 2009 location. Verification strips are seen as the three treated and untreated strips placed across the field extending through all four management zones.

impacted in untreated areas causing unnecessary loss in revenue to the grower-cooperator. The Buckeye location was an attempt to identify areas where the application rate of the nematicide could be reduced, not eliminated, in the regions of finer soil textures.

Evaluation of Crop Response

Crop response to the Telone II application was evaluated by examining the yield response in two ways including (1) the response across all soil management zones and (2) the response of the crop within each of the soil management zones. Yield data were collected at each site with a mechanical cotton harvester equipped with yield monitoring systems that measures a geo-referenced yield estimate as the harvester progresses through the field. Four different yield monitoring systems were used in these evaluations. The first two years AgLeader Technologies optical sensors, measuring instantaneous flow of seedcotton mass, were coupled to an AgLeader Insight display to collect yield data. All remaining cotton data, with the exception of the 2010 Buckeye location, were collected using Ag Leader optical sensors coupled with the CaseIH AFS Pro 600 display. Corn grain yield data at the Bonita, location in 2009 were collected using the Ag Leader grain moisture and mass flow sensors coupled to the Insight display. Yield data for the 2010 Buckeye location were collected using John Deere microwave-based cotton mass flow sensors coupled with the Greenstar 2 display. All yield monitors were calibrated utilizing either a boll buggy or a grain wagon equipped with load cells to obtain actual weights that were then used to calibrate the sensors on each harvester. These data were compiled by the same spatial management software (SMS) and then compared to the application map where yield response was evaluated across the test area. The spatial management software allows for filtering data by treated and untreated areas within each soil management zone providing for evaluation of crop response to Telone II application within each zone. The process of filtering the yield data produces a single overall mean value across the field based upon data filter parameters so statistical comparisons were not made. Table 1 outlines the locations, dates of significant operations and equipment used to carry out the evaluations.

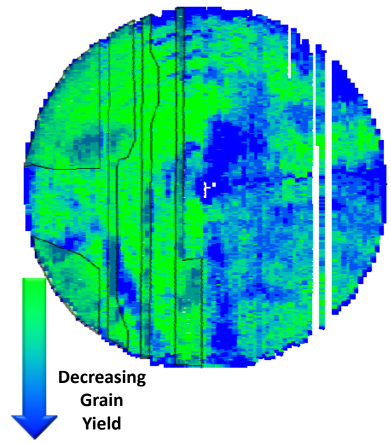

Figure 4. Grain yield map indicating yield levels from high (green) to low (blue) at the Bonita, 2009 location. Untreated areas are outlined demonstrating the differential in yield response across the various soil management zones.

Table 1. Dates of operations and equipment used to conduct precision nematode control evaluations across Arizona from 2006 through 2010.

Year	Location	Soil Survey	Application	Planted	Yield Data (Harvest)
2006	Safford, AZ	None	4/20/2006□	4/30/2006	10/23/2006□
2007	Safford, AZ	2/27/2007□	3/15/2007□	4/16/2007	11/8/2007□
2007	Coolidge, AZ	2/22/2007□	3/14/2007□	3/30/2007	11/20/2007□
2009	Bonita, AZ	3/2/2009□	4/6/2009□	5/05/2009	9/18/2009□
2009	Safford, AZ	3/5/2009□	4/20/2009□	4/18/2009	11/20/2009□
2010	Safford, AZ	1/18/2010□	3/19/2010□	4/21/2010	10/28/2010□
2010	Buckeye, AZ	2/9/2010□	3/18/2010□	4/1/2010	12/2/2010□

□EM-38DD dual dipole soil conductivity meter, Geonics Limited, Mississauga, Ontario, Canada
□Veris 3100 soil conductivity mapper, Veris Technologies, Inc., Salina KS, USA
□Raven flow sensor and boom controller coupled with Viper controller display, Raven Industries Flow Control Division, Souix Falls, SD
□Raven positive displacement injection pump coupled with Viper controller, Raven Industries Flow Control Division, Souix Falls, SD
□Ag Leader optical mass flow sensors coupled with Insight monitor, Ag Leader Technology, Ames, Iowa
□Ag Leader optical mass flow sensor coupled with Case IH AFS Pro 600, Ag Leader Technology, Ames, Iowa and Case IH, Racine WI
□Ag Leader grain mass flow and moisture sensor coupled with Ag Leader Insight display, Ag Leader Technology, Ames, Iowa
□John Deere Greenstar microwave cotton mass flow sensor coupled with Greenstar 3 (GS2630) display, Deere & Company, Moline, IL

Results

Analysis of crop response across all soil texture zones at each location is presented in Table 2. Analysis of variance for these data are also presented. A positive response was observed at all locations each year but only three of the six evaluations provided a statistically significant yield response.

Table 2. Crop response measured by analysis of mean yield data from treated and untreated verification strips across all soil management zones at each of the six trial locations across Arizona from 2007 through 2010.

	Mean Lint (lbs/acre)/Grain Yield (bu/acre)					
	---------2007---------		---------2009---------		---------2010---------	
Treatments	**Coolidge**	**Safford**	**Bonita**	**Safford**	**Safford**	**Buckeye**
Control	901.3 b*	1461.8	142.3	1116.4	1133.2	2188.4 b
Telone (3 gpa)	N/A	N/A	N/A	N/A	N/A	2291.3 ab
Telone (5 gpa)	1167.5 a	1412.3	153.6	1179.1	1181.4	2374.2 a
LSD†	114.8	NS	6.4	NS	NS	157.8
OSL‡	0.0051	0.2148	0.0170	0.2432	0.3773	0.0720
CV¶	4.9	3.1	1.2	5.3	4.5	1.6

*Means followed by the same letter are not significantly different according to a Fisher's Least Significant Difference (LSD) means separation test (α=0.1)
†Least Significant Difference
‡Observed Significance Level
¶Coefficient of Variation

Significant yield response across all soil management zones was observed in Coolidge, 2007; Bonita, 2009; and Buckeye 2010. These three evaluation sites were characterized by very high baseline nematode levels and less soil texture variability. However, the Bonita location is a bit of an anomaly. Soil texture at this location was highly variable and nematode populations were very high (approximately 800 nematodes/500cc soil) in the coarsest texture soil. The test area (60 acres) was also dominated by the coarse soil texture resulting in a positive yield response when analyzing the yield response of the full verification strips. Figure 5 illustrates the yield response at each the cotton evaluations.

Crop response to Telone II applications in all locations correlated well with soil texture zone with coarse texture soils having the largest positive response and the finer texture soils providing no yield response to the Telone II application. The response profile and distribution was slightly different in magnitude at each location but very similar patterns were observed across locations. The average yield for treated and untreated areas within soil management zones one through four is presented for each location in Table 3. The yield response at each location was greatest in zone one. Increase in yield due to Telone II applications in these zones ranged from just under 10% in Safford, 2007 to over 120% in Coolidge, 2007.

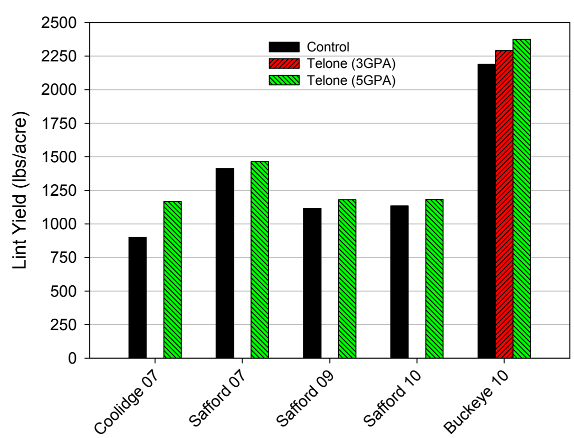

Figure 5. Yield response for all cotton evaluation locations by treatment level (0, 3, and 5 gpa rates) across all soil management zones. Yield response was statistically significant at only three of the six evaluation sites when compared across all soil management zones.

Table 3. Crop response measured by analysis of mean yield from treated and untreated areas within each soil management zone at each of the six trial locations across Arizona from 2007 through 2010.

	Mean Lint/Grain Yield												
	------------2007------------				------------2009------------				--------------------2010--------------------				
	--Coolidge--		---Safford---		---Bonita---		---Safford---		---Safford---		------Buckeye------		
	0 gpa	5 gpa	0 gpa	5 gpa	0 gpa	5 gpa	0 gpa	5 gpa	0 gpa	5 gpa	0 gpa	3 gpa	5 gpa
	------------lbs/acre------------				---bu/acre---		-----------------------------lbs/acre-----------------------------						
Zone 1	497	1116	1383	1497	123	153	840	1136	1185	1301	1994	2225	2355
Zone 2	1057	1293	1466	1493	154	163	1268	1499	1329	1302	2250	2414	2450
Zone 3	1069	1317	1495	1490	154	160	1487	1497	1209	1218	2201	2342	2400
Zone 4	1038	1154	1555	1572	153	155	1620	1592	1312	1315	2238	2306	2371

In an attempt to normalize yield response across locations and within each soil zone, percent relative yield was calculated at each location. This was accomplished by taking the average yield in the treated areas of each soil management zone and referenced it to the average yield of the untreated areas within each zone to calculate a percent response or percent relative (to the control) yield. These data for each location are presented in Figure 6.

Positive yield response was evident in zone 1 at each location and often in zone 2. At the Coolidge location positive yield response was also observed in zones 3 and 4. That similar pattern was observed in Buckeye also. The 5 gpa rate produced the highest yield response over the control, but the 3 gpa rate also provided a positive yield response over the control; however the response was greatest in zones 1 through 3. Yield response in zone 4 at the 3 gpa rate dropped off considerably.

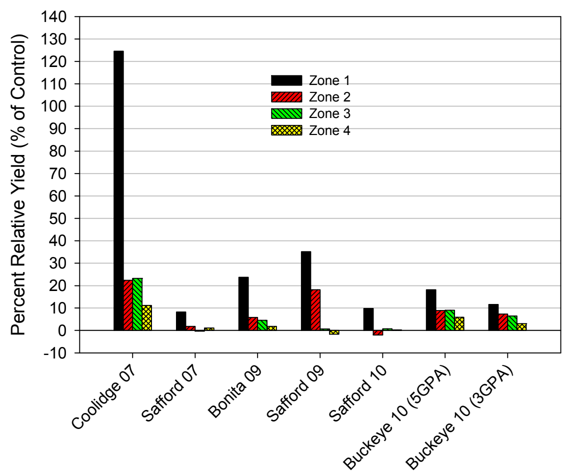

Figure 6. Percent relative yield response for all evaluation locations within each soil management zone (one through four). Relative yield response ranged from no response to over 120% of the control yield. A strong differential response by soil management zone was observed at three of the six locations.

Economic Analysis

For the grower, the question comes down to whether or not the decision to make an application of Telone II for the control of nematodes was an economically profitable one. In order to examine this we performed a basic economic analysis based upon a cotton price of $0.75 per pound and a Telone II price of $14 per gallon or $70 per acre for the 5 gpa rate and $42 per acre for the 3 gpa rate. A return on investment (ROI) was calculated for each of the evaluations. The response obtained within each soil management zone was utilized to evaluate the ROI. Figure 7 represents the ROI for each of the locations and years. Each soil management zone is represented by a different bar within each year-location. It is clearly evident that the application of Telone II was not profitable in every case. At the Safford location in 2007 and 2010 a positive ROI was obtained only in zone 1 while a grower would have operated at a loss applying the nematicide in zones 2 through 4. A similar response was observed in Bonita, 2009 and Safford 2009; however a positive ROI was observed in zone 2 at the Safford location in 2009. A positive ROI was obtained in all four zones in Coolidge in 2007 and in Buckeye in 2010 in both the high 5 gpa rate and the lower 3 gpa rate. In all cases ROI was positively correlated with increasing sand content (lower zone number) which also corresponds to increasing nematode population densities.

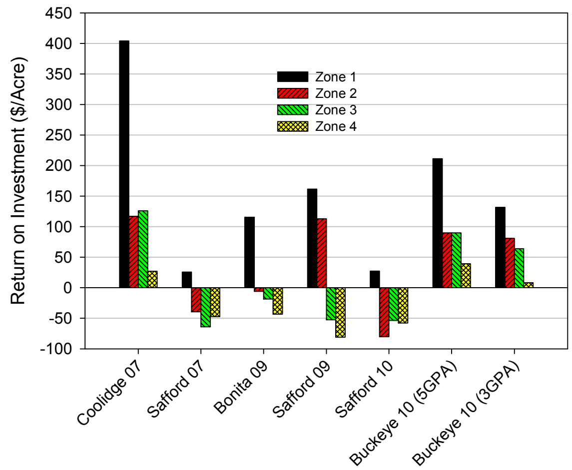

Figure 7. Return on investment (ROI) for each evaluation location within each soil management zone. A strong ROI was obtained for zone one at all locations. As soil texture increased in silt and clay content ROI decreased (zones two through four at the Safford and Bonita locations). A positive ROI was observed in zone at the Coolidge and Buckeye locations where soil texture was less variable.

Conclusions

These evaluations provide sound evidence that the technologies associated with site specific management of nematode populations in Arizona cropping systems may be successfully implemented to reduce the amount of nematicide applied to the field while maintaining adequate control of nematodes in most locations. A high degree of soil variability in these trials translated into high variability in nematode populations and greater success of site-specific management of nematode populations. This is evident in both the Safford and Bonita locations. Implementing site-specific management under these scenarios has the greatest potential to increase yields while minimizing the amount of nematicide needed to effectively control nematodes. In areas where soil texture is less variable (i.e. Coolidge and Buckeye) the implementation of these techniques is going to be less effective. However, work will continue in order to refine the characterization of the field of interest both in terms of soil texture and nematode distribution in an attempt to utilize site-specific management more effectively in scenarios of lower soil texture variability.

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