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Short- and long-term tillage effects on *Heterodera glycines* reproduction in soybean monoculture in west Tennessee☆

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ABSTRACT

Soybean cyst nematode, *Heterodera glycines* has been documented as the pathogen most consistently causing yield loss in US soybean production fields almost since its discovery in the US. No-tillage has been adopted in much of the soybean production areas to preserve soil and nutrients. The impact of this production practice change on soybean cyst nematode has been evaluated since the introduction of the practice over thirty years ago and mixed results on the impact have been recorded. This study was initiated to determine if tillage practices and timing of changes impacted soybean cyst nematode reproduction. The study was imposed on a long-term tillage study and treatments were changed to measure short-term as well as long-term effects of tillage on soybean cyst nematode. Significant differences in soybean cyst nematode population density were found between treatments. However, significant differences found could be attributed to short-term changes in tilled and no-tilled treatments. Soybean cyst nematode reproduction was almost twice as high in treatments which changed from no-tillage to disc than tilled treatments changed to no-tillage. No significant differences were found in yield among the treatments. Grain yield was reflective of cultivar grown and environmental conditions.

1. Introduction

Soybean cyst nematode (SCN), *Heterodera glycines*, Ichinohe, has been documented as the pathogen most consistently causing yield loss in US soybean production fields (Wrather and Koenning, 2006). Crop production practices have a direct or indirect effect on plant root function, and therefore the impact of tillage on root pathogenic nematodes has been of interest (Caveness, 1974; Thomas, 1978; Southards, 1971) and continues of interest. Crop rotation and use of plant resistance have long been used as methods to reduce SCN; however, these strategies reduce the risk of yield loss but do not eliminate the risk. Management strategies such as row spacing, date of planting, tillage regimes, and trap crops are some of the strategies that have been explored as additional ways to reduce the impact of SCN. Management strategies such as no-tillage, which have increased yield and reduced soil and nutrient runoff, have been explored most extensively to determine the impact on management of SCN. The effects of tillage practices on *H. glycines* reproduction have been mixed. Koenning et al. (1995), Tyler et al. (1983, 1987), Baird and Bernard (1984), and Workneh et al. (1999) all found that no-tillage decreased the population density of SCN. Chen et al. (2001), Noel and Wax (2003), and Hershman and Bachi (1995) found no effect of tillage systems on SCN population density. Several explanations have been proposed for the conflicting results. Studies such as Tyler et al. (1987) suggest that results of SCN population density are temporal in relation to the initiation of no-tillage. The above studies were direct comparisons between sites with mixed tillage histories and not systems where comparisons were made between recent changes and long-term systems.

There have been various theories concerning the abiotic and biotic effects of no-tillage on SCN reproduction. Abiotic effects include lower soil temperature, additional soil water, increased soil organic matter, changes in soil bulk density, pore size, and water infiltration rate (Bernard et al., 1996). It is well known that soil temperature is temporally lower in no-till partially due to the presence of residue (Griffith et al., 1975), and temperature is a major driving force on the length of the SCN life cycle (Ross, 1964). Optimal temperatures for SCN life stage development have been documented (Alston and Schmitt, 1988), and lower soil temperature would lengthen the life cycle and potentially reduce the number of eggs in the soil reservoir during the growing season by reducing the number of SCN generations. Soil water is interrelated

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to soil temperature. Debris on the soil surface from no-tillage conserves water near the soil surface (Tyler and Overton, 1982; Blevins et al., 1971). Heatherly et al. (1982) found SCN developed best near 0.03 MPa in the top 0.15 m of the soil profile. Johnson et al. (1993, 1994) found little direct relationship between agronomic characters and their relationship to water potential or SCN infestation level. Heatherly et al. (1992), Heatherly and Young (1991) and Young and Heatherly (1988) investigated effects of water potentials on SCN reproduction in greenhouse, microplot and field experiments and found that irrigation could not negate the stress from SCN in a susceptible cultivar. However, soil moisture may influence the establishment and location of the SCN juvenile feeding site (Endo, 1964). Increased soil water, lower soil temperatures, and non-incorporation of residue under no-tillage may result in increased organic matter as compared to soil environmental conditions with tillage (Aina, 1979; Tyler et al., 1983). Widmer et al. (2002) in a review of the effects of soil organic matter found a negative correlation between plant parasitic nematodes and increasing soil organic matter. Organic matter can increase fungal parasites of SCN (Ginitis et al., 1982, 1983). No-tillage is reported favoring an increase in facultative anaerobes (Doran, 1980). Caesar-TonThat et al. (2007) found that tillage influences soil bacteria which contribute to soil aggregates. Microaggregates stabilize soil and are thought to provide habitat for soil organisms which lead to increased soil quality. They found a wider diversity of bacteria in soil microaggregates of a no-till soil compared to tilled soil. Tillage changes the geospatial relationship of nematodes within the soil and most likely also affects the distribution of SCN antagonists (Gavassoni et al., 2001). With the mixed results in the literature we initiated this experiment to determine whether there was a tillage effect on SCN reproduction in our system and whether there were effects of long- (historical) and short-term (changed) tillage changes on SCN reproduction.

2. Materials and methods

2.1. Field site

This research was conducted from 2002 through 2005 as part of a long-term tillage experiment at West Tennessee Research and Education Center, Jackson, TN. The plot area (1 ha) had been in comparison of conventional tillage methods, disking (0.1 m deep), chisel plow (0.25 m deep), moldboard plowing (0.25 m deep), and conventional planting, to no-tillage planting in chemically killed wheat (*Triticum aestivum*) as a winter cover since 1979 (Table 1). The production crop was soybean (*Glycine max*). The soil is classified as a Lexington silt loam (fine-silty, mixed thermic ultic Hapludalf). Soil temperature data at 11 cm deep below bare soil was available from the Jackson, TN official NOAA weather station (NOAA 40-4561-4) located 0.4 km from the field plot. Results from earlier research on this experimental site using the historical tillage treatments have been reported previously (Baird and Bernard, 1984; Bernard et al., 1996; Tyler and Overton, 1982; Tyler et al., 1983, 1987; Wrather et al., 1998).

Table 1
Tillage treatments used to measure effects of long- and short-term tillage on soybean cyst nematode population density. Historical tillage was kept on half of the plot and the changed tillage was implemented on the other half in 2002.

Treatment designation	Historical tillage	Changed tillage
Disc (D)	D	D
Disc changed to no-tillage (D-NT)	D	D-NT
Chisel(C)	C	C
Chisel changed to no-tillage (C-NT)	C	C-NT
Moldboard (M)	M	M
Moldboard changed to no-tillage (M-NT)	M	M-NT
No-tillage in soybean stubble (NTS)	NTS	NTS
No-tillage changed to disc (NTS-D)	NTS	NTS-D
No-tillage with wheat cover since 1984 (NTW)	NTW	NTW
No-tillage in wheat changed to disc (NTW-D)	NTW	NTW-D
Long-term no-tillage with wheat cover since 1979 (LNT)	LNT	LNT
Long-term no-tillage changed to disc (LNT-D)	LNT	LNT-D

2.2. Tillage regime

Historical tillage treatments were arranged as a Randomized Complete block design with 4 replications and 6 tillage treatments. The 6 tillage treatments had a nested treatment structure of till (yes, no) and till treatments within till. In 2002 at the beginning of the experiment, each plot was divided in half and additional paired treatments were established. With these additional paired treatment the experimental design is a Split plot with 6 main unit treatments as described above and subunit treatments as described as follows: Plots which had been historically tilled until 2002 were changed to one half tilled as previously and the other half no-tillage. Plots which had been historically no-tilled until 2002 were changed to one half no-tillage as previously and the other half was changed to disking and leveling (Table 1). Each subunit treatment replicate was 18 m long $\times$ 6 m wide (108 m^2) with four rows 1.5 m apart.

Egg population density was collected at planting and harvest which added an additional split to the design.

A bulk soil sample was collected representative of the entire plot area each fall and sent to the University of Tennessee Soil Test Laboratory (Nashville, TN) for standard soil analysis. Fertilizer was added to the entire plot based on the Laboratory results. Previous research from these plots measured bulk density of the tillage treatments (Tyler et al., 1994; Rhoton et al., 1993).

The plots were planted with Asgrow 4702 RR May 22, 2002 and harvested October 19, 2002. In 2003 Asgrow 5901 RR was planted June 5 and harvested October 22; in 2004 Asgrow 5501 RR was planted May 21 and harvested October 28; and in 2005 Asgrow 5905 was planted May 24 and harvested October 27. Based on company information, Asgrow AG 4702 is resistant to HG Type 0-(race 3) and HG Type 1.3-(race 14), AG 5901 and AG 5501 are resistant to HG Type 0-(race 3) and moderately resistant to HG Type 1.3-(race 14), and AG 5905 is resistant to HG Type 0-(race 3). The SCN population in the plot area was characterized as HG Type 1.2.5.7 (race 2) (Niblack et al., 2003). There are few commercial soybean cultivars with resistance to HG Type 1.2.5.7 (race 2) and none of these have glyphosate resistance. Current management suggestions are to rotate cultivars when sources of resistance cannot be obtained (Niblack, 2005). These cultivars were selected based on common usage in west Tennessee, herbicide resistance, and availability of these cultivars. Herbicide applications were standard for commercial production in west Tennessee. The grain was collected using a Massey Fergusson plot combine with computerized grain weight and moisture system. Yield data was standardized to 13% moisture.

2.3. Soil sampling

Soil was sampled for SCN at planting and at harvest each year of the study. Each plot was divided into five subplots on gridlines and soil samples were collected at the center of each of these subplots for a total of 20 soil samples per treatment. Six to eight soil cores (2.5 cm diam $\times$ 20 cm deep) were collected at each subplot point, bulked by subplot in a plastic bag and transported to a cold room (4 °C) until processed.

2.4. Soil analysis

Soil samples for SCN were screened through 1/4 "mesh hardware cloth, thoroughly mixed and a 120 cm^3 subsample