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Long-term effects of residue and water management practices on plant parasitic nematode abundance and soybean root infection

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ABSTRACT

Soil-borne, plant parasitic nematodes are potentially agronomically and economically damaging in the wheat (*Triticum aestivum* L.)-soybean (*Glycine max* L.), double-crop production system that is common in the mid-southern United States. Double-crop field studies with at least five years of consistent management are rare, but can provide a valuable setting to assess long-term, and potentially cumulative, management practice effects on nematode abundance and root damage. The objective of this study was to evaluate the effects of a combination of management practices including residue burning (burned and no burn)-irrigation (irrigated and non-irrigated), wheat residue level (high and low), and tillage (conventional tillage and no-tillage) practices on plant parasitic nematode soil abundance and reproduction on soybean 34 and 70 days after planting following 14 complete cropping cycles in a wheat-soybean, double-crop production system on a silt-loam soil in eastern Arkansas. Stunt and total nematode abundances were at least 8.2 and 4.2 times greater ($P < 0.05$), respectively, under the burn-non-irrigated-no-tillage than under the other three burn-irrigation-tillage treatment combinations 34 and 70 days after planting. Root-associated soybean cyst nematode egg concentrations were 16.2 and 4.5 times greater under the burn-non-irrigated-low-residue than under the no-burn-irrigated-low-residue and burn-non-irrigated-high-residue treatment combinations, respectively, which did not differ, 34 days after planting, but were unaffected by any field treatment 70 days after planting. Producers may consider avoiding the combination of residue burning, no-tillage, and dryland soybean production to help keep the parasitic nematode population low. Results of this long-term field support the notion that properly managed crop rotations contribute enough diversity of inputs and processes to limit the known negative effects of continuous monoculture.

1. Introduction

Plant parasitic nematodes are potentially damaging pests in numerous upland, cultivated, row crops (Koenning et al., 1999), particularly in the Lower Mississippi River Valley (Heatherly and Young, 1991) and specifically for soybean (*Glycine max* L.) grown in eastern Arkansas (Robbins et al., 1987; ASPB, 2017). A variety of nematode genera have been shown to cause substantial soybean yield loss (Rebois and Johnson, 1973; Young, 1996), even without visual aboveground plant symptoms (Noel, 1992; Young, 1996).

Soybean is commonly grown in a double-cropping system with wheat (*Triticum aestivum* L.) in the Lower Mississippi River Valley. The traditional set of management practices include nitrogen fertilization for optimal wheat grain and maximal residue production followed by wheat residue burning and conventional tillage to prepare for soybean planting followed by irrigated soybean production. Nematode abundance and/or crop impacts have been reported to be affected by various crop management practices, including irrigation/soil moisture content (Heatherly and Young, 1991; Johnson et al., 1993a,b, 1994; Koenning and Barker, 1995), nitrogen fertilizer source and amount (Rodriguez-Kabana, 1986), and tillage (Parker et al., 1975; Tyler et al., 1987; McSorley and Gallaher, 1993; Noel and Wax, 2003).

Crop rotation has also been shown to affect nematode abundance and/or crop impacts (Ferris and Bernard, 1970; McSorley and Gallaher, 1993; Johnson et al., 2000; Noel and Wax, 2003). Furthermore, crop rotation has been identified as an effective management strategy to control and minimize nematode impacts in soybean production (Johnson et al., 1994). However, conversion from a monoculture to a crop rotation and/or conversion from traditional to alternative soil and crop management practices are an ecosystem disturbance that requires

Abbreviations: ANOVA, analysis of variance; B, burn; CT, conventional tillage; DAP, days after planting; DM, dry matter; EC, electrical conductivity; H, high residue level; I, irrigated; L, low residue level; NB, non-burned; NI, non-irrigated; NT, no-tillage; RCB, randomized complete block; SOM, soil organic matter; TC, total carbon; TN, total nitrogen

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some time for the ecosystem, including nematodes and other soil biota, to regain a new, stable equilibrium.

Producers have recently been faced with numerous agronomic decisions with regards to residue (i.e., residue burning or no burning and conventional or conservation tillage) and water management (i.e., irrigated or dryland production) to improve sustainability and/or economic returns within the wheat-soybean, double-crop production system. However, little field research has been conducted evaluating the effects of burning on nematode abundance and/or nematode-associated plant impacts. Consequently, understanding the impacts of alternative residue and water management practices, coupled with the potential effects on parasitic nematodes, on soybean production will be important to achieving environmental, agronomic, and economic sustainability. Therefore, the objective of this field study was to evaluate the effects of a combination of residue burning-irrigation, wheat residue level, and tillage practices on plant parasitic nematode soil abundance and reproduction on soybean roots 34 and 70 days after soybean planting following 14 complete cropping cycles in a wheat-soybean, double-crop production system on a silt-loam soil in eastern Arkansas. It was hypothesized that nematode soil abundance and soybean root infection would be less under conventional tillage and dryland soybean than under no-tillage and irrigated soybean production due to differences in the degree of physical soil disturbance and soil moisture conditions between tillage and irrigation treatments.

2. Materials and methods

2.1. Site description

Research was conducted during the 2016 soybean growing season at the Lon Mann Cotton Branch Experiment Station (N34°, 44′, 2.26″, W90°, 45′, 51.56″) near Marianna, AR in Major Land Resource Area 134, Southern Mississippi Valley Loess (Brye et al., 2013). The 2016 soybean growing season followed 14 consecutive cropping cycles in a long-term, wheat-soybean, double-crop production system that was initiated in Fall 2001 (Cordell et al., 2007). The mapped soil throughout the study site is the loess-derived, Calloway silt-loam (fine-silty, mixed, thermic, Glossaquic Fragiudalfs; Natural Resource Conservation Service (NRCS, 2017). Brye et al. (2006) confirmed the soil texture in the top 10 cm was silt loam, with 16% sand, 73% silt, and 11% clay. Prior to Fall 2001, the study area was uniformly cropped to monoculture soybean for at least three years using conventional tillage (Brye et al., 2006). Consequently, near-surface soil properties throughout the study area were assumed to be as uniform as could reasonably be expected, so that any subsequent measured differences were due to imposed treatments rather than due to inherent differences within the study area.

The climate throughout the region is warm and wet. The 30-yr (1981–2010) mean annual air temperature is 16.6 °C, with a mean monthly minimum of −0.6 °C in January and a mean monthly maximum of 32.9 °C in July (NOAA, 2017). The 30-yr mean annual precipitation is 128.4 cm (NOAA, 2017). Actual on-station rainfall during the 2016 soybean growing season (i.e., May through October) total 45 cm, which was relatively evenly distributed throughout the growing season such that no water stress was anticipated that could have affected grain yield.

2.2. Long-term study history and plot management

Beginning in November 2001, and every Fall thereafter, the study area was bulk-planted to a ‘Coker’ wheat variety. In early Spring 2002, the study area was divided into 48 individual plots, 6-m long by 3-m wide, followed by a split application of nitrogen (N) as urea (46% N), where the first application was made in late-February to early March and the second application was made approximately one month later to create differing amounts of aboveground wheat residue (Table 1). Between 2002 and 2004, 101 kg N ha^{-1} were manually broadcast to all plots at the first application timing. An additional 101 kg N ha^{-1} were manually broadcast to 24 plots at the second application timing to create a high-residue treatment, while the remaining 24 plots received no additional N to create the low-residue treatment. Between 2005 and 2015, a total of 112 kg N ha^{-1} was applied, half at each timing, to maintain the high-residue treatment, while no N was applied to maintain the low-residue treatment. Plots remained as either high- or low-residue treatments every year for the duration of the long-term study. To confirm differential residue levels were achieved, residue levels were measured prior to wheat harvest each year, which occurred with a research-grade, plot combine by approximately early-June.

Table 1
Summary of typical management practices and their schedule in the wheat-soybean, double-crop production system at the Lon Mann Cotton Branch Experiment Station near Marianna, AR.

Agronomic activity	Approximate timing of activity
Wheat planting	Early November
Nitrogen fertilization of wheat	
First application	Late February to early March
Split application	Late March to early April
Wheat harvest	Early June
Residue burning	Early June
Conventional tillage	Early June
Soybean planting	Mid- to late June
Irrigation	Late June to late September
Soybean harvest	Late October to early November

Following wheat harvest each year, half of the high- and low-residue plots were manually burned by propane flaming, while the other half of the plots were left unburned. Successful residue burning was achieved in 13 of 15 years, with the exception of in 2005 and 2008 when no wheat crop was established due to wet-soil conditions at wheat planting in Fall 2004 and due to an excessive ryegrass (*Lolium perenne* L.) infestation that did not senesce and dry down in time, respectively. Following imposition of the burn treatment each year, half of the plots were conventionally tilled (CT), which typically consisted of three passes with a tandem disk to a depth of 5–10 cm followed by three passes with a field cultivator to break up soil clods and smooth the seed bed, while the other half of plots was left as no-tillage (NT) prior to soybean planting. Between 2002 and 2013, a glyphosate-resistant, maturity group 4–5, soybean cultivar was drill-seeded with 19-cm row spacing by mid- to late June each year, while, between 2014 and 2016, a Liberty-Link, ‘Armor’ cultivar was planted to combat increasing weed densities. Between 2002 and 2004, the entire study area was furrow-irrigated with local groundwater as-needed during vegetative and/or reproductive growth three to four times each year. In 2005, and for each year thereafter, the study area was split in half, such that 24 plots remained furrow-irrigated, while the other 24 plots were non-irrigated as dryland soybean were produced. Consequently, in addition to natural rainfall, the irrigated plots received an additional 23–30 cm of irrigation. The study area was uniformly sprayed with herbicide typically twice after soybean establishment each year to control weeds. Soybean were harvested each year between late October and early November with a plot combine, after which the next cropping cycle began. Table 1 summarizes the typical agronomic activities and their timing during an annual cycle of the wheat-soybean, double-crop system.

2.3. Treatments and experimental design

Between 2002 and 2016, the entire study area consisted of three replications of 16 residue-water management treatment combinations arranged in a randomized complete block (RCB) experimental design, where there were three tillage blocks stripped across burn and irrigation blocks and each tillage plot was split with a high- and low-residue treatment. However, for the purposes of this field study, only extreme treatment combinations were used, which consisted of both tillage