Growth and Yield of Winter Wheat as Affected by Preceding Crop and Crop Management

Randy L. Anderson*

Wheat

ABSTRACT

Producers in eastern South Dakota are interested in adding winter wheat (*Triticum aestivum* L.) to their crop rotations to improve crop yield and pest management. Our study quantified winter wheat response to preceding crop and crop management. Preceding crops were soybean [*Glycine max* (L.) Merrill], oat (*Avena sativa* L.)–pea (*Pisum sativum* L.) mixture, and spring wheat. Two crop management strategies, high-input and conventional, were compared. High-input management differed from conventional management by a 60% higher seeding rate and a split application of N fertilizer. Winter wheat with high-input management yielded the highest following oat–pea; in contrast, winter wheat with conventional management yielded 28% less following spring wheat. Winter wheat following soybean yielded 88% of the winter wheat with high-input following oat–pea. Tiller density was 32% higher when winter wheat followed oat–pea compared with soybean. Winter wheat developed faster following oat–pea compared with other preceding crops, as determined by measuring solar radiation at the soil surface in early May and date of heading. Winter wheat production can be improved by increasing seeding rate and banding a starter fertilizer by the seed at planting.

Producers in eastern South Dakota are interested in diversifying the corn (*Zea mays* L.)-soybean rotation to improve pest management. Corn rootworm (*Diabrotica* spp.) has adapted to the corn-soybean rotation by laying eggs in soybean fields, thus minimizing the benefit of rotating corn and soybean for its management (Levine et al., 2002). Yield losses due to the soybean cyst nematode (*Heterodera glycines* Ichinohe) continue to increase (Noel and Edwards, 1996). Furthermore, weeds with similar life cycles have proliferated in the corn-soybean rotation and are increasing weed management costs (Gibson et al., 2006). Adding different crops to this rotation will likely help manage these pests (Anderson et al., 2006).

One potential crop is winter wheat, as improved cultivars have expanded successful production to colder climatic regions (Thiessen Martens et al., 2001). In addition to improving pest management, including winter wheat in the corn-soybean rotation may help producers develop no-till systems to preserve soil quality. Initial research found that corn and soybean often yielded less in no-till compared with conventional-till systems (Dick and van Doren, 1985; Lund et al., 1993). However this yield loss in no-till was eliminated when other crops were added to the rotation.

In addition, the favorable effect of no-till on soil structure and aggregation is enhanced by including small grain crops such as winter wheat with corn and soybean in rotation (Bezdicek and Granatstein, 1989; Raimbault and Vyn, 1991). Studies in the eastern Corn Belt region have found that corn yield can increase more than 40% in a winter wheat-corn-soybean rotation compared with corn-soybean, which was attributed to winter wheat improving soil structure over time (Zhang et al., 1996; Katsvairo et al., 2002).

Producers are asking for information on winter wheat production to aid in planning rotations. For example, if winter wheat follows corn, yield will be reduced because of the late planting date (Stymiest et al., 2000), whereas *Fusarium* head blight is favored by this sequence (Dill-Macky and Jones, 2000). A more favorable sequence would be planting winter wheat after soybean; however, yield may still be reduced by the late planting date (Peterson et al., 1991; Lund et al., 1993). A further concern with this sequence is that the lack of residue cover may accentuate winter injury (Andrews et al., 1997). Producers can grow winter wheat after spring wheat to improve residue stubble for snow management and winter protection (Stymiest et al., 2000). However, this sequence may increase root diseases in winter wheat (Krupinsky et al., 2002). Another option is to grow winter wheat after an oat–pea mixture for forage; winter wheat will be planted during its optimal planting date range, and both oat and dry pea improve winter wheat growth by suppressing root diseases (Lockie et al., 1995; Bourgeois and Entz, 1996). Oat will provide stubble for snow management.

Producers may be able to adjust cultural tactics with winter wheat to improve productivity. Increasing seeding rate may compensate for the late planting of winter wheat after soybean (Dahlke et al., 1993), whereas banding phosphorus with winter wheat seed may minimize impact of root diseases and increase winter hardiness (Cook, 1991). The objective of this study was to examine the impact of preceding crop and crop management on growth and yield of winter wheat. Our goal is to provide guidance for producers with winter wheat production choices.

USDA-ARS, Brookings, SD 57006. Received 7 June 2007. *Corresponding author (randy.anderson@ars.usda.gov).

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MATERIALS AND METHODS

Site Characteristics

The study was established on a Barnes clay loam (fine-loamy, mixed, superactive, frigid Calcic Hapludolls) near Brookings, SD (44°18′ N, 96°47′ W). The soil contains approximately 3% organic matter and soil pH ranges from 6.8 to 7.2. Yearly precipitation is 537 mm (84-yr average), with May, June, and July receiving the highest rainfall. Cropping history for the study site was corn-soybean for the previous 10 yr. The field was split, with both corn and soybean grown in each year; the study was established in corn stubble.

Treatments

Six treatments, consisting of three preceding crops and two management systems in winter wheat, were established with no-till across a 2-yr interval. The preceding crops, soybean, oat–pea mixture for forage, and spring wheat, were established and harvested in the first year. Winter wheat was planted in the fall of the first year, and harvested in the second year. The study was arranged in an experimental design of a 3 (preceding crop) by 2 (winter wheat management) factorial, with the six treatments randomized in a complete block. Treatments were replicated four times and plot size was 7 m by 15 m. The study was conducted in 2001 to 2002, 2002 to 2003, and 2003 to 2004; for each 2-yr interval, the study was established at a different location in the same field.

Spring wheat 'Russ' was planted at 129 kg ha^{-1} in early April of 2001, 2002, and 2003, whereas oat–pea, consisting of a 2:1 mixture of Austrian winter pea and 'Jerry' oat, was planted at 166 kg ha^{-1}, also in early April. Soybean, Stine 099, was planted between 15 May and 25 May of each year, with a target population of 400,000 seeds ha^{-1}.

Nitrogen as ammonium nitrate was applied broadcast at 95 kg N ha^{-1} to spring wheat when plants were tillering. A starter fertilizer of 18 kg P ha^{-1} plus 15 kg K ha^{-1} was applied between the seed rows of soybean at planting. No fertilizer was applied to oat–pea. Weeds were controlled by bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) in spring wheat and by glyphosate [2-(phosphonomethylamino)acetic acid] in soybean; weeds did not establish in oat–pea. Oat–pea was harvested for forage in late July, whereas spring wheat and soybean were harvested for grain in early August or late September, respectively. Grain yield was 2960 kg ha^{-1} for spring wheat and 2350 kg ha^{-1} for soybean, averaged across 3 yr; forage yield for oat–pea was 5610 kg ha^{-1}.

Winter wheat was established in residue of the three preceding crops in the fall of 2002, 2003, and 2004. In all years, 'Harding' winter wheat was planted between 10 September to 15 September in oat–pea and spring wheat residue, whereas winter wheat was planted in soybean stubble either 30 September or 1 October, which was within 1 d of soybean harvest. Two management systems were compared. A conventional system with a seeding rate of 1.8 million seeds ha^{-1} and N fertilizer applied in the spring when plants were tillering. High-input management consisted of a seeding rate of 3 million seeds ha^{-1} with N fertilizer applied two times, a starter fertilizer at planting and a broadcast application at tillering. Nitrogen fertilizer rates for winter wheat were based on a yield goal of 4700 kg ha^{-1} and were adjusted for preceding crop (Gerwing and Gelderman, 2002). The N rate applied to winter wheat was 130, 140, and 150 kg N ha^{-1} following soybean, oat–pea, and spring wheat, respectively. Starter fertilizer consisted of 15 kg N ha^{-1} + 18 kg P ha^{-1} applied with the seed. A low density of broadleaf weeds infested the study sites and was controlled by bromoxynil at 0.4 kg ha^{-1} applied in early May.

Measurements with Winter Wheat

Penetration of solar radiation to the soil surface during the winter wheat growing season was measured by a hand-held linear PAR/LAI ceptometer (Model PAR-80, Decagon Devices, Pullman, WA). Readings were recorded near noon on days without cloud cover. For the ground measurement, the ceptometer was randomly placed diagonally across three planted rows of winter wheat; immediately after the ground measurement, an above-canopy light reading was also recorded with the ceptometer. Two measurements were taken for each plot when winter wheat following oat–pea was in early stem elongation, which occurred between May 5 and May 10 in all years. Light penetration was determined by converting radiation quantity reaching the ground surface to a percentage of radiation recorded by the above-canopy measurement.

The date of heading, defined as when the spike was 2 cm above the collar of the flag leaf, was recorded for each treatment by classifying nine random plants. Three plants were assessed at three locations in each plot daily until heading occurred. Each plant was rated according to the Zadoks-Chang-Konzak scale, which designates plant development from when awns of the spike are just visible to anthesis on a scale of 1 to 10 (Bauer et al., 1983).

Grain yield was obtained by harvesting the center 3 m by 15 m with a plot combine (Kincaid Equipment Manufacturing, Haven, KS). Moisture concentration of grain samples was determined with an electronic moisture meter and sample weights were adjusted to 13.5 g kg^{-1}. Yield components were determined from one 1-m^2 quadrat in each plot collected before harvesting the plot. Samples were stored in a greenhouse until processed. Number of spikes were counted, seed threshed with a bundle thresher (Kincaid Equipment Manufacturing, Haven, KS) and 500-kernel weight was determined for each grain sample. Kernels per spike were calculated from yield, spike density, and kernel weight of each sample. A subsample of grain from each plot was dried, ground, and analyzed for total N using Kjeldahl digestion and steam distillation (Bremner, 1982).

Statistical Analysis

Data were initially tested for homogeneity of variance among years, and then subjected to ANOVA for a randomized complete block design with a factorial structure to determine treatment effects and possible interactions among treatments and years (Analytical Software, 2003). Main and interaction effects were considered significant at $P \leq 0.05$; treatment means were separated by the Fisher's Protected LSD. With date of heading, the standard error of each treatment mean was also calculated.

RESULTS AND DISCUSSION

Data analysis indicated that a year by treatment effect did not occur, so data are averaged across years. A significant interaction occurred between preceding crop and winter wheat management for grain yield and date of heading, therefore

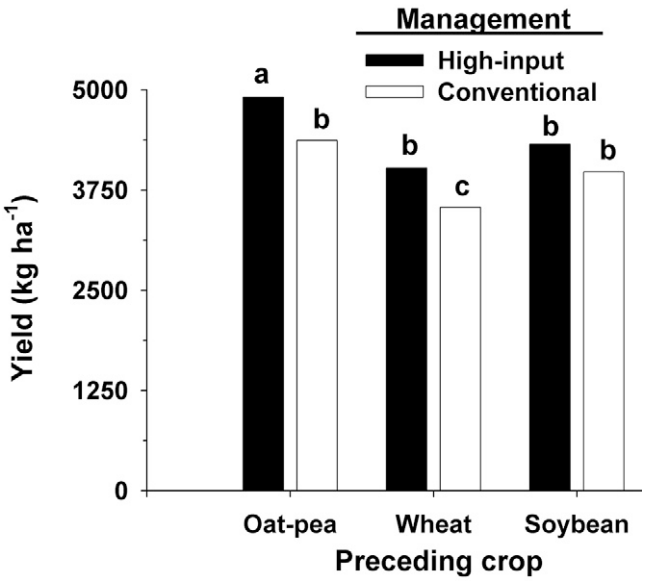

Fig. 1. Yield of winter wheat, as affected by preceding crop and crop management. High-input management included 60% higher seeding rate and starter fertilizer banded with the seed. Data averaged across 3 yr; bars with same letters are not significantly different as determined by Fischer's Protected LSD (0.05).

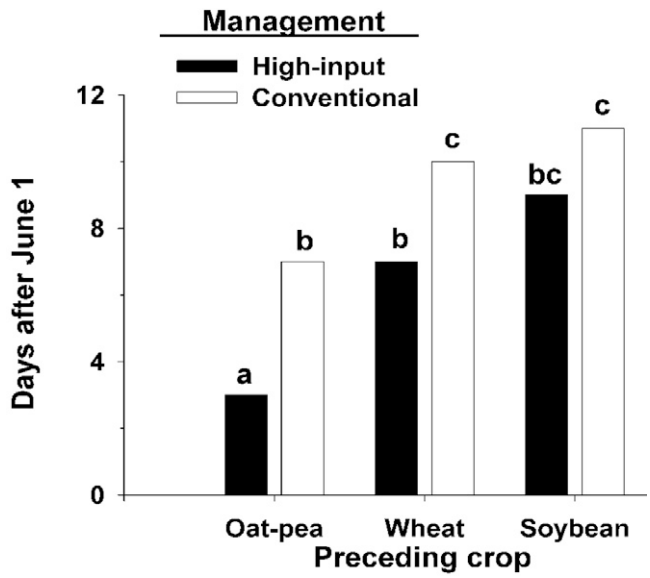

Fig. 2. Date when the spike of winter wheat was at least 2 cm above the flag leaf collar, as affected by preceding crop and crop management. High-input management included 60% higher seeding rate and starter fertilizer banded with the seed. Data averaged across 3 yr; bars with the same letters are not significantly different as determined by Fischer's Protected LSD (0.05).

data of these parameters are expressed separately (Fig. 1 and 2). An interaction between main factors did not occur with the remaining parameters, so data for these parameters are expressed by main effect only (Table 1).

Yield and Components of Yield

Winter wheat yielded the highest with high-input management following oat–pea; in contrast, yield was 28% less when winter wheat with conventional management followed spring wheat, a decrease of 1375 kg ha^{-1} (Fig. 1). Yields differed between management treatments when oat–pea and spring wheat were the preceding crops, but not with soybean. Winter wheat yielded the same with high-input management when following soybean and spring wheat, even though winter wheat following soybean was planted 2 to 3 wk later. This effect as well as the favorable impact of oat–pea on winter wheat yield may be related to suppression of root diseases (Wildermuth and McNamara, 1991). Other research has shown that oat (Lockie et al., 1995), pea (Stevenson and Van Kessel, 1996), and soybean (Vyn et al., 1991) can reduce root disease severity in wheat.

Tiller density varied among preceding crops (Table 1). Winter wheat following oat–pea produced 549 tillers m^{-2}, or 32% more than winter wheat following soybean. Tiller density was also 14% higher following oat–pea compared with spring wheat as a preceding crop. High-input management increased tiller density 35% compared with conventional management, which we attribute to higher seeding rate and starter fertilizer. Winter wheat compensated somewhat for low tiller density by increasing kernels spike^{-1} when following either soybean or spring wheat (Table 1). A similar trend occurred between crop management treatments; plants in the conventional management produced more kernels spike^{-1}. Kernel weight was not affected by treatment (data not shown); averaged across all treatments, 500 kernels weighed 14.4 g.

Nitrogen content in grain did not vary with crop management, but N content was more than 1 g kg^{-1} lower when winter wheat followed soybean compared with the other preceding crops. We cannot explain why N concentration in grain was lower when winter wheat followed soybean. Our yield goal for calculating N fertilizer rate was 4700 kg ha^{-1}. Winter wheat following soybean yielded 4200 to 4400 kg ha^{-1}, thus fertilizer rate was adequate.

Light Penetration and Canopy Development

Adding winter wheat to the corn-soybean rotation may help weed management because its growth period is different than corn or soybean (Anderson et al., 2006). One reason for this benefit is that seedlings of weeds common in corn and soybean often cannot establish in winter wheat because of reduced solar radiation through the crop canopy (Lemerle et al., 1996). In our study, less than 30% of solar radiation reached the soil surface in early May when winter wheat followed oat–pea because

Table 1. Yield components, protein concentration of winter wheat seed, and light penetration as affected by crop management and preceding crop. Data averaged across 3 yr. Means within a column for a specific factor (preceding crop or winter wheat management) followed by the same letter are not significantly different as determined by Fischer's Protected LSD (0.05). Higher values of light penetration indicate less canopy development.

	Yield components			
Factor	Tillers	Kernels spike^{-1}	Total N grain^{-1}	Light penetration
	no. m^{-2}	no.	g kg^{-1}	%
Preceding crop				
Oat–pea	549 a	17.6 b	23.1 a	40 c
Spring wheat	475 b	19.6 a	22.8 a	59 b
Soybean	416 c	20.1 a	21.4 b	81 a
Winter wheat management†				
Conventional	409 b	20.5 a	22.5 a	68 b
High-input	551 a	17.6 b	22.3 a	52 a

† Conventional management consisted of planting winter wheat at 1.8 million seeds ha^{-1} with N fertilizer applied in the spring; high-input management consisted of winter wheat planted at 3.0 million seeds ha^{-1}, starter fertilizer banded with seed at planting, and the remainder of N applied in the spring.

of a dense canopy development; in contrast, more than 80% of solar radiation reached the soil surface when winter wheat followed soybean because of a less-developed canopy (Table 1). High-input management also increased light interception compared with conventional management. Because of slower canopy development, weed growth may be considerably greater when winter wheat follows soybean compared with oat–pea as a preceding crop.

Date of heading for winter wheat was affected by an interaction between preceding crop and management. Winter wheat with high-input management following oat–pea completed heading by 3 June (Fig. 2). In contrast, heading occurred 5 to 7 d later when winter wheat followed either spring wheat or soybean. Also, variability in development was prominent when winter wheat with conventional management followed spring wheat. The standard error was fivefold greater with this treatment compared with oat–pea as a preceding crop (data not shown). Banding P with the seed and increasing the seeding rate eliminated this variability with the spring wheat–winter wheat sequence.

CONCLUSIONS

Winter wheat may be a viable cropping option for producers in eastern South Dakota. Winter wheat responded favorably to management choices such as seeding rate and fertilizer management. Producers may further increase winter wheat yield with other management tactics, such as split applications of N fertilizer in the spring (Scharf and Alley, 1993) or applying fungicides to suppress leaf diseases (Kelley, 1993). Winter wheat yielded well following soybean (88% of oat–pea with high-input management). This may be a favorable sequence for producers, as winter hardiness is being improved in newer cultivars (Thiessen Martens et al., 2001). Winter wheat development was variable following spring wheat, but this response was eliminated by banding P with the seed and increasing seeding rate.

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