No-tillage soybean performance in cover crops for weed management in the western cornbelt

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No-tillage soybean performance in cover crops for weed management in the western Corn Belt

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ABSTRACT: Frequency of soil moisture depletion and subsequent crop yield reduction resulting from water use by cover crops is unclear. Effects of cover crop residues and irrigation on soybean emergence, canopy volume, grain yield, and soil moisture in eastern Nebraska were determined. Cover crop treatments included five common species and a bare soil control. Precipitation treatments included rainfed conditions and weekly irrigation events of 18 mm (0.7 in) in June and July. Above-normal May rainfall in 1995 and 1996 resulted in similar percent volumetric soil water contents (%VSWC) in the surface 15.2-cm (6.0-in) soil layer. Soybean emergence was unaffected by residue dry matter levels below 3,170 kg/ha (2,830 lb/ac). Early-season soybean growth was similar across all treatments; however, cover crop biomass greater than 2,170 kg/ha (1,940 lb/ac) reduced soybean canopy volume 33 to 44% during mid-season droughts. Yields were highest when stand densities were maintained and weeds were suppressed. This research develops a greater understanding of how cover crop residues influence soybean performance, ultimately reducing reliance on postemergent herbicide use for weed control in no-tillage systems.

Key words: Allelopathy, canopy volume, crop residues, fitness, integrated weed management, no-tillage, soil moisture, soil temperature, weather variability.

Cover crops are considered a tool in integrated weed management and control off-season soil and nutrient losses in row-crop production (Altieri and Liebman 1988; Swanton and Weise 1991). Residues on the soil surface with no-tillage management can reduce or delay crop and weed seedling recruitment, survival, and growth by altering the light environment, modifying soil temperatures, releasing allelochemicals, and acting as a physical barrier to emerging seedlings (Facelli and Pickett 1991). Allelochemicals have been isolated from commonly-studied cover crops, including barley (*Hordeum vulgare* L.), rye (*Secale cereale* L.), wheat (*Triticum aestivum* L.), and hairy vetch (*Vicia villosa* Roth.) (Shilling et al. 1985; White et al. 1989; Lovett and Hoult 1995). These residues inhibit growth of the foxtail species (Setaria spp.) and pigweed species (Amaranthus spp.) (Putnam et al. 1983; Mohler and Teasdale 1993). Several authors have demonstrated that weed suppression by cover crops complements effectiveness of reduced-rate herbicide programs in horticultural crops (Burgos and Talbert 1996; Wallace and Bellinder 1992).

Some studies have evaluated the suitability of cover crop systems for weed management in no-tillage soybean [*Glycine max* (L.) Merr.] production. In four years of a 5-yr study, soybean yielded significantly higher and weed biomass was reduced 74% to 91% in fall-planted rye compared to bare soil (Warnes et al. 1991). Improved soybean yields in two of three years corresponded with greater than 65% weed control from cover crop residues at 4 and 10 wk after planting (Liebl et al. 1992). Soybean yields in several winter cereal mulches were similar to yields in bare soil in four location-year experiments, except in one case where yields were improved by rye and triticale (*X Triticosecale*) residues that provided early-season weed suppression (Moore et al. 1994).

One concern about the use of cover crops in dryland agriculture is that these cover crops use soil moisture needed by the succeeding crop in dry years. Delaying the date of killing the cover crop maximizes biomass production, assisting in weed suppression in the absence of tillage (Mohler and Teasdale 1993). However, allowing continued vegetative growth, particularly during a low-precipitation spring, may deplete stored soil moisture. In one of two years in Illinois, late-killed rye resulted in a 5-cm (2-in) loss of soil water (0-to-60 cm profile) in mid-June (Liebl et al. 1992). In Ontario, Wagner-Riddle et al. (1994) observed that rye killed 1 to 2 wk before planting reduced soil water content in one out of four sites/year combinations. Hairy vetch killed with a herbicide at corn planting in Nebraska had depleted soil moisture 3.1% compared to bare soil in the top 15 cm (5.9 in) in one out of four years (Power et al. 1991). Apparently, cover crops do not limit soil moisture for a succeeding crop in the Corn Belt every year. Less clear is the frequency of both soil moisture and crop yield reduction resulting from water use by cover crops.

Maintaining plant residues on the soil surface, as in the case of no-tillage crop production, can enhance soil moisture by decreasing runoff and evaporation (Adams et al. 1976). Liebl et al. (1992) found the upper 25 cm (9.8 in) of the soil profile had a higher %VSWC than bare soil for two rye kill dates when residues were left undisturbed on the soil surface. Likewise, Wagner-Riddle et al. (1994) saw an increase in soil water early in the soybean growing-season in one of four location-year experiments. In another study, rye mulch conserved soil moisture during drought periods of early corn and soybean growth, enabling greater plant water use deeper in the soil profile late in the season (Gallaher 1977).

Soil moisture is the most limiting resource in a rainfed environment; therefore, cover crops must be managed to minimize water stress on the subsequent crop. Although several studies have evaluated the impact of cover-crop mulches on soil water content in Illinois (Liebl et al. 1992) and Ontario (Wagner-Riddle et al. 1994), it is not known whether these results apply in the western Corn Belt where precipitation is more limited. Research indicates cover crops are valuable in Nebraska for soil stabilization (Walters 1987) and green manuring (Power et al. 1991). Cover crop growth characteristics and optimal planting dates have been identified for a sub-humid region (Power 1991; Power and Koerner 1994). However, few studies have characterized no-tillage soybean germination, growth, and yield in cover crop residues for weed management under contrasting

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Table 1. Cover crop management.

Cover crop	Year					
	1995			1996		
	Seeding rate	Spray date	Biomass	Seeding rate	Spray date	Biomass
	- kg/ha -		- kg/ha -	- kg/ha -		- kg/ha -
Barley	78.4	6 June 1995	3170	78.4	23 May 1996	130
Rye	78.4	6 June 1995	6310	78.4	13 May 1996	2890
Triticale	156.4	6 June 1995	7160	78.4	13 May 1996	750
Wheat	78.4	6 June 1995	6710	78.4	23 May 1996	2170
Vetch	—	—	—	35.8	23 May 1996	650
LSD (0.05)			780			330

soil moisture conditions.

The objectives of these field experiments were to identify how a cover crop mulch system for weed control influences soybean emergence, canopy growth, grain yield, and soil moisture under rainfed and irrigated conditions. The hypothesis being tested was that soybean has a unique set of environmental conditions (e.g., cover crop species and %VSWC) that optimize emergence, growth, and yield in cover crop residues.

Materials and methods

Site description. Field experiments were initiated in the fall of 1994 and 1995 at the University of Nebraska Agricultural Research and Development Center near Ithaca, Neb. Cover-crop treatments were planted on September 7 each year in fields where corn had been harvested for silage the preceding week (Table 1). The soil at both locations, 3.8 km (2.4 mi) apart, was a Sharpsburg silty clay loam (fine, montmorillonitic, mesic, typic Argiudoll). The soil at the first-year site contained 2.6% organic matter with a pH of 6.3, while the soil for the second-year site contained 2.8% organic matter and a pH of 5.8.

Experimental design and treatment structure. The experimental design was a randomized complete-block design with 3 replications in the fall of 1994, and 4 replications in 1995. Each block was randomized individually as a stripped split plot (split-block) with vertical strips of a "cover" treatment factor and horizontal strips of a "water" treatment factor (horizontal strips orthogonal to vertical strips). "Cover" treatment levels in 1994 included a bare soil control plot, as well as barley (cv. Perkins), rye (cv. VNS), triticale (cv. Newcale), and wheat (cv. Arapaho), which were no-till drilled 2 cm (0.8 in) deep on 25-cm (9.8-in) rows in 31.0 m (100 ft) (15 ft x 4.6 m)) plots. Two additional cover crops were added in 1995: hairy vetch and a 1:1 ratio mixture of red clover (*Trifolium repens* L. cv. Mammoth) and yellow sweetclover [*Melilotus officinalis* (L.) Pall.]. Two "water" treatment levels included presence and absence of irrigation.

Cover crops were killed in the spring of each year (Table 1). In 1995, glyphosate [N-(phosphonomethyl) glycine] was applied over the entire experimental area at 2.2 kg ai/ha (2.0 lb/ac) with a tractor-mounted compressed-air sprayer at a carrier volume of 187 L/ha (20 gal/ac). In 1996, rye and wheat were killed with a hand-held CO_2 pressurized backpack sprayer at 1.1 kg ai/ha (1.0 lb/ac) of glyphosate and 187 L/ha (20 gal/ac) on May 13. Ten days later, the entire experimental site was sprayed with 1.4 kg ai/ha (1.3 lb/ac) of glyphosate. Since glyphosate had only a minor effect on hairy vetch, this cover crop species was clipped at the soil surface by hand within one week after herbicide application. Because of severe winterkill in the clover mixture, data were not collected from this treatment.

On June 7, 1995, and May 21, 1996, 250,000 seeds/ha (100,000 seeds/ac) of "Dunbar" soybean (group III indeterminate) were no-till planted 2 cm (0.8 in) deep in 76-cm (30-in) rows. A Buffalo-Till 4500-6AA (Fleischer Manufacturing, Columbus, Neb.) planter was used in 1995 and a Case 900 Cycloair (Case Corporation, Racine, Wisc.) planter the following year. A sprinkler irrigation system was assembled to irrigate randomly-assigned subplots measuring 7.6 x 4.6 m (25 x 15 ft). The irrigated plots received approximately 18 mm (0.7 in) of water applied weekly in June and July (Figures 1c and 2c).

Cover crop treatment provided the only means of weed suppression the first 5 wk after soybean planting. Grasses, predominantly foxtails *(Setaria spp.)*, were controlled with 0.3 kg/ha (0.3 lb/ac) of sethoxydim [2-[1-(ethoxyimino)butyl]5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one] plus recommended adjuvants applied with a tractor-mounted compressed-air sprayer on July 9, 1995, and July 2, 1996. Weeds other than redroot pigweed (*Amaranthus retroflexus* L.) and common waterhemp (*Amaranthus rudis* Sauer) were removed by hand.

Microsite conditions. Cover crop biomass was determined within 3 days of spraying by clipping the above-ground cover crop biomass in each of four 0.14 m^2 (1.5 ft^2) quadrant frames per plot. Biomass samples were then oven-dried and weighed.

Percent volumetric soil water content (%VSWC) estimates were based on soil sampling in both years. Methods are described in detail (Williams et al. 1998). Rain gauges in irrigated plots and weather data from the automated weather station at the research site provided precipitation amounts. The %VSWC was rarely measured immediately after irrigation; however, %VSWC at this time was estimated based on %VSWC measured prior to irrigation and the amount of water applied during irrigation (assumed 0% evaporatory loss of sprinkler irrigation water). Volumetric soil water content at 60% water-filled pore space (WFPS) was 31.0 at the 0-to-15.2 cm (6.0 in) soil depth, where WFPS = %VSWC ÷ soil porosity, and soil porosity = (1 - soil bulk density ÷ 2.65).

Soil maximum-minimum thermometers were used to monitor temperature fluctuations at a 1.3-cm (0.5-in) soil depth. Soil temperature was recorded and thermometers were reset approximately every third day during emergence. Mean soil temperature was calculated from maximum-minimum values.

Sampling and analytical procedures. Soybean seedling emergence in 1995 was monitored along 1 m (39 in) of crop row within each subplot. Emerged soybean seedlings were counted approximately every 5 days the first 4 wk after planting. Emergence was defined as the point at

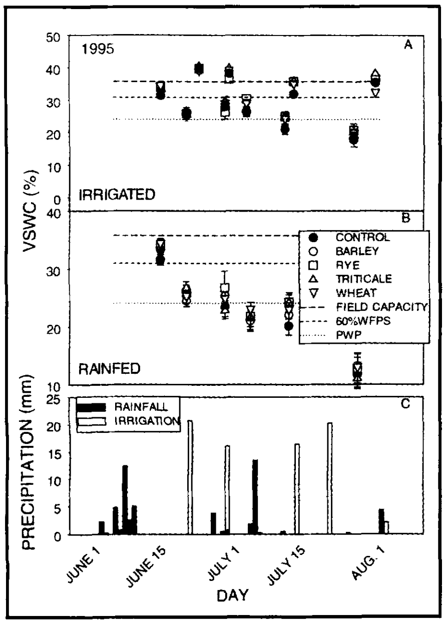

Figure 1. Percent volumetric soil water content (%VSWC) in (A) irrigated and (B) rainfed plots in 1995 (0-to-15.2 cm soil depth). Each estimate is a mean of 3 replicates and 2 samples. Bulk density, averaged over treatments, was 1.28 g/cm³. PWP (1500 kPa) and field capacity (30 kPa) are for a benchmark Sharpsburg soil. Standard error bars are presented. (C) Daily rainfall and irrigation in 1995.

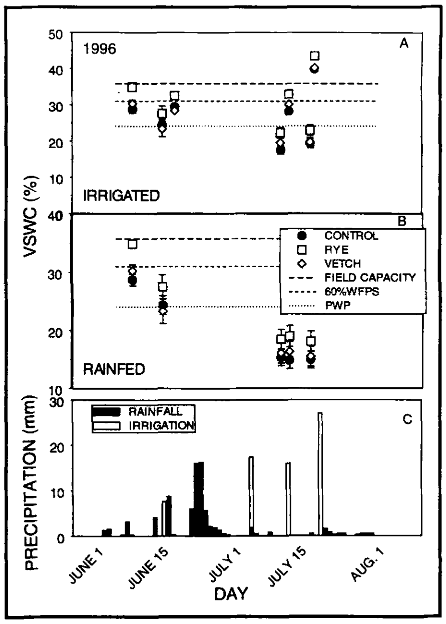

Figure 2. Percent volumetric soil water content (%VSWC) in (A) irrigated and (B) rainfed plots in 1996 (0-to-15.2 cm soil depth). Each estimate is a mean of 4 replicates and 10 samples. Bulk density, averaged over treatments, was 1.28 g/cm³. PWP (1500 kPa) and field capacity (30 kPa) are for a benchmark Sharpsburg soil. Standard error bars are presented. (C) Daily rainfall and irrigation in 1996.

which cotyledons protruded above the soil. Sampling was expanded to include three 1-m (39-in) lengths of crop row within each subplot in 1996.

Five soybean plants in 1995, and three in 1996, were randomly selected for non-destructive growth assessment approximately 2 wk after planting. Crop height was measured from the soil surface to the growing point, and maximum plant width was measured perpendicular to the crop row at 50% height. Based on measurements of row height and width, soybean canopy volume (m^3/m^2) was determined. Approximately 130 days after planting (DAP), grain yield was determined by hand-clipping three 1-m (39-in) lengths of crop row, and then threshing and drying composite soybean seed to a constant weight.

Statistical analysis. Seedling emergence, canopy growth, and grain yield were analyzed with analysis of variance using the SAS MIXED model (SAS 1995). Main effects and interactions were examined and treatment comparisons were made with protected LSD tests at the 95% confidence level. Since there were significant year by treatment effect interactions, data were not pooled over years.

Results and discussion

Precipitation, cover-crop biomass, and soil water. A relatively wet spring and dry summer characterized both 1995 and 1996. The first year, precipitation in May was 144 mm (5.7 in), while June, July, and August were 33 mm (1.3 in), 21 mm (0.8 in), and 30 mm (1.2 in), respectively. The following year, 178 mm (7.0 in) of precipitation fell during May, while the next three months totaled 60 mm (2.4 in), 9 mm (0.4 in), and 25 mm (1.0 in), respectively. For comparison, the 30-yr average for these four months is 110 mm (4.3 in), 106 mm (4.2 in), 80 mm (3.1 in), and 92 mm (3.6 in), respectively. Due to the timing of rainfall events in the spring of 1995, glyphosate was applied to cover crops 3 wk later than planned. As a result, more than 3,100 kg/ha (2,800 lb/ac) of aboveground biomass was present in barley and more than 6,300 kg/ha (5,600 lb/ac) of rye, triticale, and wheat (Table 1). Dry conditions in the fall of 1995 and the spring of 1996 reduced survival of barley, triticale, and hairy vetch, resulting in 130 kg/ha (120 lb/ac), 750 kg/ha (670 lb/ac), and 650 kg/ha (580 lb/ac) of biomass, respectively. Of the species studied, rye and wheat survival and biomass production were consistently high in both years.

Throughout 1995, soils in the cover crop treatments and bare soil had similar %VSWC in the 0-to-15.2 cm (0-to-6.0 in) profile (Figure 1a, b). Likewise, in 1996, soils, rye, hairy vetch, and the control treatments had similar %VSWC with one exception; 15 DAP (June 5) when soils with rye had a higher %VSWC (Figure 2a, b). Although soil sampling in 1995 was limited to a depth of 15.2 cm (6.0 in), samples were taken to a depth of 30.5 cm (12.0 in) the following year and no apparent differences in the %VSWC at the 15.2-to-30.5 cm (6.0-to-12.0 in) depth were detected. Apparently, soil moisture used by cover crops during growth was replenished by spring precipitation in both years.

Irrigation in June and July of both years increased %VSWC relative to the rainfed treatment (Figure 1a, b; Figure 2a, b). Lack of precipitation events in June and July frequently reduced the 0-to-15.2 cm (0-to-6.0 cm) soil profile below PWP.

Soybean emergence. The presence of all residues suppressed soybean emergence early and reduced final soybean plant densities 34% (barley) to 60% (rye) (Figure 3a). Poor seedling emergence in cover crop residues in 1995 was likely the result of insufficient soil/seed contact. Because most residues exceeded 6,310 kg/ha (5,630 lb/ac), an unusually large amount of residue was left on the soil surface. Slightly higher soil moisture content in residue treatments observed at soybean planting further complicated planting operations and the front coulter of the planter had difficulty cutting through cover crop residues. As a result, residue was pressed into a *moist furrow, preventing* the furrow from closing. High residue levels have interfered with soybean planting in other studies, particularly where planting equipment failed to penetrate surface residues (Eckert 1988; Hovermale et al. 1979; Liebl et al. 1992; Wagner-Riddle et al. 1994).

Conditions were drier at planting in 1996, and lower amounts of cover crop residue [130 to 2,890 kg/ha (120 to 2,580 lb/ac)] resulted in more effective seed placement. With the exception of wheat residue at 11 DAP, cover crop residues did not delay soybean emergence, and final soybean plant densities were similar among cover crops (Figure 3b).

Soybean growth. Measurement of plant volume as an indicator of size provides a non-destructive index of plant

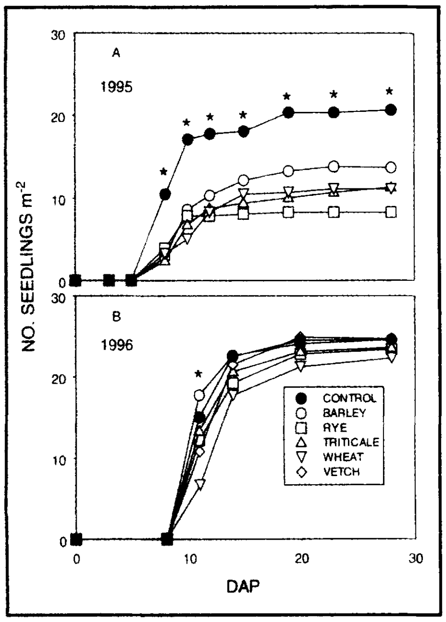

Figure 3. (A) Soybean emergence in 1995 (cover/time p-value = 0.0001). Each estimate is a mean of 3 replicates and 2 water levels. (B) Soybean emergence in 1996 (cover/time p-value = 0.0025). Each estimate is a mean of 4 replicates, 2 water levels, and 3 samples. An asterisk (*) indicates statistical differences in cover treatment levels for given sampling period. Note: poor seed-to-soil contact in 1995.

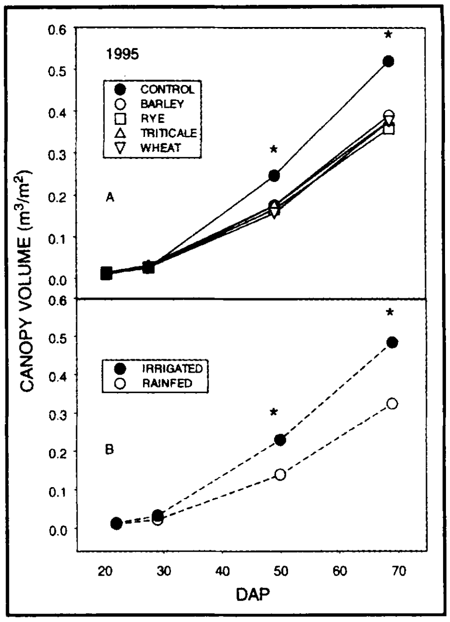

Figure 4. (A) Effect of cover crop on soybean canopy volume in 1995 (cover/time p-value = 0.0001). Each estimate is a mean of 3 replicates, 4 water levels, and 5 plants. (B) Effect of water on soybean canopy volume (water*time p-value = 0.0001). Each estimate is a mean of 3 replicates, 5 cover levels, and 5 plants. An asterisk (*) indicates statistically significant differences in treatments $\alpha = 0.05$).

Table 2. Effects of cover and water treatments on no-tillage soybean grain yield.

	Soybean yield			
	Individual		Total	
Treatment	1995	1996	1995	1996
	g/plant		kg/ha	
Cover				
Control	13.9	5.6	2060	1200
Barley	12.3	6.1	1630	1480
Rye	12.8	9.2	1540	2190
Triticale	13.2	6.0	1800	1440
Wheat	15.0	9.1	1920	1960
Vetch	—	7.4	—	1700
LSD (0.05)	(NS)	(2.7)	(230)	(630)
Water				
Irrigated	16.0	7.1	2150	1610
Rainfed	10.9	7.4	1430	1710
	(*)	(NS)	(*)	(NS)
Interactions				
Cover/water	NS	NS	*	NS

*** Significant at the 0.05 probability level.**

weight, and in the case of many annual species, seed production (Bussler et al. 1995). Canopy volume, as it was measured in this study, characterized the *space occupied* by the above ground portion of the soybean row. In making comparisons across treatments, plant biomass per unit of canopy volume is assumed constant.

The presence of cover crop residues in 1995 reduced mid-season soybean canopy volume. Early in the season, canopy volumes were similar in all cover-crop residues, yet by 50 DAP, canopy volumes in all residue treatments were less than the bare soil control (36% less with wheat, and 29% less with triticale) (Figure 4a). The 1995 canopy volume measurements probably reflect the soybean plant density differences in which the presence of residues resulted in 34 to 60% fewer seedlings. Reduced plant densities may have altered morphology of individual plants, with less vertical growth and greater between-plant growth in residue treatments. This would explain similar per plant soybean grain yield (Table 2) in all cover crop residues, ranging from 12.3 g/plant (0.43 oz/plant) in barley, to 15.0 g/plant (0.53 oz/plant) in wheat. Therefore, while a lower seedling population in cover-crop residues reduced soybean canopy growth, individuals in all treatments had the same fitness at the end of the season.

Soil moisture limited soybean canopy volume in 1995 (Figure 4b). June and July precipitation was 52 mm (2.0 in), considerably less than the 30-yr average of 189 mm (7.4 in). Although soil moisture was slightly lower in the control plots at 35 DAP (July 12), the fact that %VSWC was below the PWP indicates plants obtained adequate soil moisture from below the 15.2-cm (6.0-in) soil depth to sustain soybean growth during moisture stress periods (Figure 1a, b). On several occasions, more soil moisture was available in irrigated plots. Consequently, canopy volume was greater in irrigated plots beyond 50 DAP (Figure 4b).

In 1996, the presence of rye and wheat residues delayed initial soybean canopy development. The presence of rye and wheat residues reduced mid-season canopy volume 50 and 54%, respectively (Figure 5). Stone and Taylor (1983) found taproot and lateral root extension increases with soil temperature. Rye residue resulted in a lower rate of soil warming. For instance, rye treatments took approximately 2 wk longer for mean soil temperature at the 1.3-cm (0.5-in) depth to reach 26 °C (79° F) (Figure 6b). It is plausible that the delay in soil warming through 36 DAP delayed soybean canopy growth through 63 DAP.

Reduced early-season soybean canopy volume in 1996, as well as emergence, may also have been due in part to allelopathic compounds originating from decaying cover crop residue. Primary compounds and metabolites inhibiting germination and growth of a number of plant species have been isolated from barley, rye, wheat, and hairy vetch (Shilling et al. 1985; White et al. 1989; Lovett and Hoult 1995). In addition, frequent irrigation and natural precipitation events may have enhanced conditions favoring anaerobic microbial activity under high residue levels (Williams et al. 1998). As a result, phytotoxic compound production may have occurred several weeks after cover crop death. For instance, acetic acid is released from decomposing wheat straw (Lynch 1977).

The presence of cover crop residues resulted in greater canopy size later in the 1996 season due in part to weed suppression. At 3 wk after planting, *Amaranthus spp.* canopy volume was reduced 38, 71, 48, 58, and 67% by presence of barley, rye, triticale, wheat, and hairy vetch residues, respectively (Williams et al. 1998). With respect to the bare soil treatment, soybean canopy volume increased 16, 27, and 28% in barley, wheat, and hairy vetch residues at 79 DAP, respectively (Figure 5). In addition, individual soybean grain yield was 9.2 g/plant (0.32 oz/plant), 9.1 g/plant (0.32 oz/plant), and 7.4 g/plant (0.26 oz/plant) for rye, wheat, and hairy vetch residues (Table 2), on average 54% higher than the control and indicating a larger canopy biomass by harvest in these residues. Apparently, early-season suppression of weeds by the presence of cover-crop residues reduced weed competitiveness and increased soybean fitness.

Soybean grain yield. An interaction between cover crop and water on soybean grain yield was observed in 1995 (Table 3). Under irrigation, with the exception of the presence of rye, which reduced yields 11%, soybean yields in the bare soil and cover crops were not significantly different. However, in the absence of supplemental irrigation water, the presence of residues resulted in significantly lower soybean yields. Since per plant grain yields were identical across all cover treatments (Table 2), differences in total yields were a function of soybean density. As discussed earlier, interference with planting operations from crop residue has lead to decreased soybean yields in other investigations (Eckert 1988; Liebl et al. 1992).

In 1996 the presence of rye, wheat, and vetch residues resulted in higher soybean grain yields compared to the bare-soil treatment (Table 2). Despite the slight delay in soybean emergence in the presence of wheat residue and mid-season stunting by the presence of rye and wheat residue, soybean in those environments yielded 990 kg/ha (880 lb/ac) and 760 kg/ha (680 lb/ac) more than the bare soil control. As mentioned earlier, suppression of weeds by the presence of cover crop residues early in the season may have

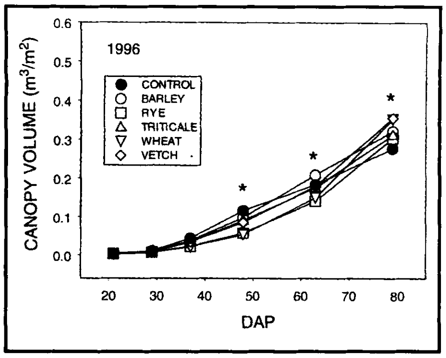

Figure 5. Effect of cover crop on soybean canopy volume in 1996 (cover*time p-value = 0.0148). Each estimate is a mean of 4 replicates, 2 water levels, and 3 plants. An asterisk '*' indicates statistically significant differences in treatment (α = 0.05).

reduced their competitive effect on the crop. When cover crop residues minimized weed competition, other studies have found enhanced crop yields (Warnes et al. 1991; Liebl et al. 1992; Moore et al. 1994).

Conclusions

Winter cover crops play a role in soil and water conservation and integrated weed management in soybean throughout the Corn Belt. They also can be used in semiarid regions provided the dynamic resource needs of the crop are met. Our findings in eastern Nebraska indicate no-tillage soybean can yield well in residues when cover crop residues do not reduce soybean stand densities. Soybean emergence declined as cover crop biomass rates exceeded approximately 3,100 kg/ha (2,800 lb/ac). Williams et al. (1998) found *Amaranthus spp.* and *Setaria spp.* growth are reduced 37% to 97% at 3 to 5 wk after planting into cover crop residues with biomass levels as low as 130 kg/ha (120 lb/ac). Furthermore, early-season soybean growth is frequently placed at a competitive advantage over that of the weeds.

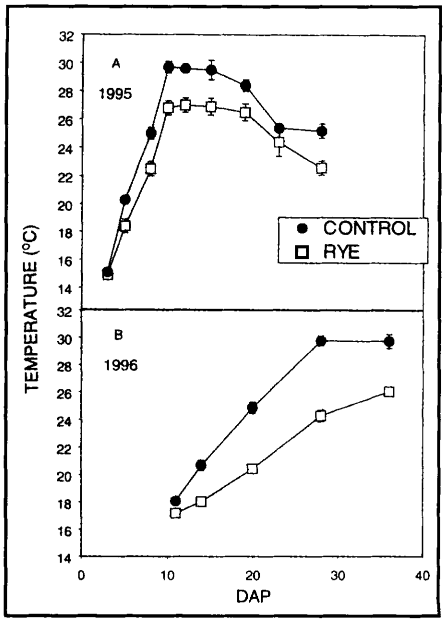

Figure 6. Mean soil temperature at 1.3-cm depth. (A) 1995 estimates are a mean of 3 replicates and 4 thermometers. (B) 1996 estimates are a mean of 4 replicates and 4 thermometers. Standard error bars are presented.

In both years of this research, above-normal precipitation in May was followed by below-normal precipitation in June, July, and August. Transpirational demands from cover crops coincided with high precipitation events, explaining why %VSWC in cover-crop treatments were never lower than the control.

Additional research needs to look more closely at year-to-year variability in weather patterns and how they influence cover-crop water usage and soybean performance under dryland conditions. Ultimately, coupling such modeling efforts with recent findings on weed suppression will provide the necessary framework for establishing guidelines that minimize yield-reducing risks of using cover crops, as well as maintain the crop at a competitive advantage over the weeds. Exploiting crop and weed selectiv-

Table 3. Effects of cover and water treatments on no-tillage soybean grain yield in 1995.

Cover	Yield: Irrigated	Yield: Rainfed
	kg/ha	
Control	2150ab	1980a
Barley	2160ab	1100c
Rye	1910b	1170c
Triticale	2200ab	1410bc
Wheat	2330a	1510b
LSD (0.05)	350	

Within columns, means followed by the same letter are not significantly different at LSD (0.05).

ity to cover crops offers an approach to conserve both soil and water resources in no-tillage systems that historically rely heavily upon herbicides for weed control.

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