Legume Green Fallow Effect on Soil Water Content at Wheat Planting and Wheat Yield

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ABSTRACT

Growing a legume cover crop in place of fallow in a winter wheat (*Triticum aestivum* L.)–fallow system can provide protection against erosion while adding N to the soil. However, water use by legumes may reduce subsequent wheat yield. This study was conducted to quantify the effect of varying legume termination dates on available soil water content at wheat planting and subsequent wheat yield in the central Great Plains. Four legumes [Austrian winter pea, *Pisum sativum* L. subsp. *sativum* var. *arvense* (L.) Poir.; spring field pea, *P. sativum* L.; black lentil, *Lens culinaris* Medikus; hairy vetch, *Vicia villosa* Roth.) were grown at Akron, CO, as spring crops from 1994 to 1999. Legumes were planted in early April and terminated at 2-wk intervals (four termination dates), generally starting in early June. Wheat was planted in September in the terminated legume plots, and yields were compared with wheat yields from conventional till wheat–fallow. Generally there were no significant differences in available soil water at wheat planting due to legume type. Soil water at wheat planting was reduced by 55 mm when legumes were terminated early and by 104 mm when legumes were terminated late, compared with soil water in fallowed plots that were conventionally tilled. Average wheat yield was linearly correlated with average available soil water at wheat planting, with the relationship varying from year to year depending on evaporative demand and precipitation in April, May, and June. The cost in water use by legumes and subsequent decrease in wheat yield may be too great to justify use of legumes as fallow cover crops in wheat–fallow systems in semiarid environments.

The limited and highly variable precipitation of the semiarid central Great Plains resulted in the traditional winter wheat–fallow crop production system used to stabilize yields (Haas et al., 1974; Hinze and Smika, 1983). That system, especially with the use of tillage to control weeds during the fallow period, leaves the soil surface vulnerable to soil loss and degradation by wind erosion and has very low precipitation storage efficiency (Tanaka and Aase, 1987; Black and Bauer, 1988; Steiner, 1988; Farahani et al., 1998). The introduction of no-till, chemical fallow has reduced the potential for wind erosion and organic matter loss (Bowman et al., 1999), and increased stored soil water available for crop production (Peterson et al., 1996; Nielsen et al., 2002), but has introduced the potential for development of herbicide-resistant weeds when the same herbicide is continually used in the system (Westra, 2004).

A possible solution is the use of legume cover crops during the fallow period, which could protect the soil from erosion while providing organic matter and fixing N to maintain soil quality (Biederbeck et al., 1998). Such a system has been referred to as *green fallow* (Gardner et al., 1993). These systems have sometimes been successful in the cooler regions of the northern Great Plains (Zentner et al., 2001). Zentner et al. (2004) reported that early legume planting and termination dates as well as effective snow catch before spring wheat planting were essential for success with a legume green fallow system in southwestern Saskatchewan. In Montana, lentils grown to full bloom did not reduce subsequent spring profile water compared with tilled or chemical fallow. However, wheat yields in the lentil–spring wheat system were lower than in the wheat–fallow system during the first three cycles of the system due to lower available N following lentil (Cochran and Kolberg, 2002). In some other studies wheat yields following the green fallow period have been decreased due to lower soil water content at wheat planting (Zentner et al., 1996; Schlegel and Havlin, 1997) or due to N deficiency (Pikul et al., 1997). Under the higher temperature, higher evaporative demand environmental conditions of the central Great Plains, the positive economic trade-off between water used by the legumes and their favorable rotation and N fixing effects have not been observed (Vigil and Nielsen, 1998). The objectives of this study were (i) to determine the effect of legume termination date (using four legume species) on available soil water content at winter wheat planting and subsequent wheat yield in a central Great Plains environment, and (ii) to verify the conclusions of Vigil and Nielsen (1998) using a longer study period (6 vs. 2 yr).

MATERIALS AND METHODS

This study was conducted at the USDA Central Great Plains Research Station, 6.4 km east of Akron, CO (40°09′ N lat, 103° 09′ W long, 1384 m). The soil type was a Weld silt loam (fine, smectitic, mesic Aridic Argiustols). The experiment was established in 1994 on a site that had been in a dryland winter wheat–corn (*Zea mays* L.)–summer fallow rotation the previous 3 yr. Before planting the first legume crop, the corn stalks from the 1993 crop were mowed with a flail mower, raked, and removed as bales.

The experiment was arranged in a randomized split-block design with each block replicated four times. Two adjacent areas were alternated each year between legume green fallow/conventional fallow plots and the following winter wheat plots (i.e., both the fallow phase and the wheat phase of the experiment appeared each year). A replication consisted of four main plots, 9.1 m wide and 19.5 m long. The four main-plot treatments consisted of three legume species and a traditional summer fallow treatment. Four legume species were investigated in this study, but only three were tested in any given year (Table 1). In preliminary work (Vigil and Nielsen, 1998), lentil was found to produce less biomass for the same amount of water use as the other legumes, and was therefore replaced

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Published in Agron. J. 97:684–689 (2005).
doi:10.2134/agronj2004.0071

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Abbreviations: AWP, Austrian winter pea; FP, field pea; HV, hairy vetch; IHL, Indianhead lentil.

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Table 2. Green fallow (Apr.–Sept.) and wheat year (Oct.–June) precipitation (mm), Akron, CO.

Wheat year	Apr.–Sept.	Oct.–Feb.	Mar.	Apr.	May	June	Oct.–June	PE-precip.†
				mm				
1994–1995	193	145	22	63	144	122	496	177
1995–1996	446	35	29	10	112	66	252	510
1996–1997	424	37	2	20	55	78	192	544
1997–1998	298	111	4	17	23	10	165	800
1998–1999	214	54	8	50	78	63	253	517
1999–2000	446	54	40	37	19	19	169	839
				Avg.				
1994–2000	337	73	18	33	72	60	255	565
1908–2002	332	65	21	42	75	62	265	

† PE−precip. = pan evaporation − precipitation totaled over April, May, and June of the wheat growing season.

RESULTS AND DISCUSSION

Precipitation was above normal during the green fallow (April–September) periods of 1995, 1996, and 1999, below normal during the green fallow periods of 1994 and 1998, and near normal during the green fallow period of 1997 (Table 2). Precipitation was above normal during the wheat growing season (October–June) of 1994–1995, below normal during the wheat growing seasons of 1996–1997, 1997–1998, and 1999–2000, and near normal during the wheat growing seasons of 1995–1996 and 1998–1999. Nielsen et al. (2004) have shown the high correlation between winter wheat yields in the central Great Plains and total precipitation received in May and June for conditions when soil water at wheat planting was greater than 170 mm in the 0.00- to 1.20-m soil profile of a Weld silt loam. Total precipitation received in May and June was much below average during the 1997–1998 and 1999–2000 wheat years, near normal for the 1996–1997 and 1998–1999 wheat years, and above normal for the 1994–1995 and 1995–1996 wheat years.

The two most limiting factors to production of winter wheat grain yield in the central Great Plains are water and N (Nielsen and Halvorson, 1991). Measurements of NO_3–N and NH_4–N taken just before winter wheat planting (Table 3) indicate that significant differences in both NO_3–N and NH_4–N were observed before wheat planting the first 2 yr of the study (1994 and 1995). Those years were the establishment years for each location phase of the study. After the establishment years no significant differences were observed in available N levels between the fertilized fallow plots and the unfertilized legume plots (except for the NH_4–N measurement in March 1998 for the 1997–1998 wheat crop). In 1996, 1997, 1998, and 1999 available N levels were not yield limiting but were adequate to very high (Davis et al., 2002) in all plots including the legume treatments. Therefore, we feel confident in attributing yield differences noted in the following discussion to differences in available water caused by the presence of legumes.

The differences in green fallow period precipitation are reflected in the relative amounts of available soil water at wheat planting in the fallow plot (Table 4), with the highest amounts recorded in 1996 and 1999, and the lowest amount observed in 1994. Within a given year, there was no significant effect of legume species on available soil water at wheat planting (averaged over the four termination dates), except in 1998 when available soil water following field pea was 34% higher than observed following Austrian winter pea or lentil. We were not able to identify a reason for this higher water content following field pea in this 1 yr. For each of the six years of the study, available soil water at wheat planting was lower following legume grown during the fallow period than soil water in the conventional till fallow treatment. Averaged over the 6 yr of the study and the four legume termination dates, available soil water at wheat planting was 84 mm lower following a pea green fallow treatment (i.e., available soil water at wheat planting following a pea green fallow treatment was only 74% of the amount available in the traditional fallow treatment). Lentil and vetch were not considered in this average assessment since they were not present in all 6 yr of the study.

Available soil water at wheat planting was significantly reduced (Table 5) with delay in legume termination in every year, except 1997 when all legume plots were terminated on 23 June due to heavy weed pressure. For each of the 6 yr of the study available soil water at wheat planting for each of the four legume termination dates was lower than in the conventional till fallow treat-

Table 3. Amount of NO_3–N and NH_4–N in the surface 0.60 m of the soil profile before winter wheat planting in September in a winter wheat–legume fallow rotation.

	1994		1995		1996		1997†		1998		1999	
Treatment	NO_3–N	NH_4–N	NO_3–N	NH_4–N	NO_3–N	NH_4–N	NO_3–N	NH_4–N	NO_3–N	NH_4–N	NO_3–N	NH_4–N
							kg ha^{-1}					
Austrian winter pea	35	7	3	5	51	11	64	9	34	10	76	13
Field pea	31	7	5	4	43	11	45	9	24	11	59	14
Lentil	35	6	2	5	42	10						
Hairy vetch							58	10	32	11	71	14
Fallow	56	19	23	5	60	14	64	19	25	10	59	14
$P > F$	<0.01	<0.01	0.05	0.40	0.16	0.44	0.07	<0.01	0.16	0.62	0.38	0.81

† Due to a scheduling conflict, the data that would normally have been collected in September 1997 before winter wheat planting was not collected until March 1998 at spring greenup of winter wheat.