Long-Term Experiments at Columbia Basin Agricultural Research Center at Moro and Center of Sustainability at Heppner, 2005-2006

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Abstract

This project has now completed 3 crop years of experimentation. Three more crop years are required for all crop rotations to complete a full cycle. This report covers the 2005-2006 crop-year results. Columbia Basin Agricultural Research Center (CBARC) experiment (Moro): Spring barley produced the highest yields followed by yields of winter wheat after conventional fallow or winter wheat after chemical fallow in a 3-year rotation with spring barley. Yields of winter wheat following chemical fallow (2-year rotation) were significantly lower than yields of continuous spring barley and winter wheat after conventional fallow or after chemical fallow in a 3-year rotation with spring barley. Continuous winter wheat had the lowest yields, probably due to a combination of weeds (downy brome) and diseases (Fusarium crown rot and root-lesion nematodes) but not due to a shortage of water. On average (2004-2005 and 2005-2006), wheat following chemical fallow in a 3-year rotation with spring barley produced the highest yields although these yields were not significantly different from yields of wheat after conventional or chemical fallow (2-year rotations). In rotations involving annual cropping, continuous spring barley produced the highest yields followed by winter wheat after winter pea. Continuous winter wheat produced the lowest yields over the 2 crop years. Center of Sustainability (Heppner): Continuous spring barley produced the highest grain yields followed by winter wheat following fallow (conventional or chemical). The lowest yield was obtained from continuous spring wheat.

Introduction

The winter wheat-summer fallow rotation reduces soil organic carbon, exacerbates soil erosion, and is not biologically sustainable. Despite these concerns, adoption of alternate cropping systems, such as intensive cropping and direct seeding, has been slow due to lack of long-term research on viability of alternate cropping systems in Oregon. Occasional crop failures occurred under long-term conventional intensive cropping studies conducted at the Sherman Experiment Station in the 1940's to the 1960's. But with the advent of new varieties and agronomic practices such as direct seeding, long-term research is needed to evaluate benefits and risks for annual cropping. The main focus of the experiment is to establish and maintain long-term experiments that compare the conventional wheat-fallow system with alternate cropping systems that use crop management practices such as direct seeding, which reduce wind and water erosion. Specific objectives are to increase residue cover, increase soil organic matter, increase available soil moisture, reduce soil erosion, reduce soil water evaporation, and sustain crop productivity. This research is targeted for Agronomic Zones 4 and 5 in northcentral Oregon.

Methods and Materials

CBARC, Moro

The experiment was established on a 28-acre site at the Sherman Experiment Station in Moro in the fall of 2003. The experiment has completed 3 crop years (2003-2004, 2004-2005, and 2005-2006). The soil is a Walla Walla silt loam (coarse, silty, mixed, mesic Typic Haploxeroll) and is greater than 4 ft deep. The station receives an average of 11.5 inches of annual precipitation. Rainfall and soil at the station are representative of the average conditions in the target area.

Treatments

Crop rotations under evaluation are shown in Table 1. Each phase of each rotation appears every year. The treatments are replicated three times. There are 14 plots per replication and the minimum plot size is 48 ft by 350 ft, bringing the minimum total experimental area to 13.88 acres. Agronomic practices (planting date, planting rate, and fertilizer, herbicide, seed-treatment fungicide, and insecticide application) are based on the treatment in question. Direct seeding is conducted using the Fabro® drill (Fabro Enterprises Ltd., Swift Current Saskatchewan) purchased with assistance from the Sherman Station Endowment Fund.

Table 1. Cropping system treatments at the Sherman County Experiment Station, Moro, Oregon.

Rotation	Description
1	Winter wheat–conventional fallow (2 strips in rotation)
2	Winter wheat–chemical fallow (2 strips)
3	Continuous winter wheat (1 strip)
4	Continuous spring wheat (1 strip)
5	Continuous spring barley (1 strip)
6	Winter wheat–spring cereal (barley)–chemical fallow (3 strips)
7	Winter wheat–winter pea (2 strips)
8	Flex crop (2 strips)

Field operations: Winter wheat ('Stephens') for rotation 1 was seeded on October 10, 2005, using the HZ drill at 18 seeds/ft^2 (88 lbs/acre). 'Stephens' wheat for rotations 2, 3, 6, and 7 was direct-seeded at 20 seeds/ft^2 (98 lbs/acre[1]) at a depth of about 1 inch on October 19 and 20, 2005, using a Fabro® drill. Different fertilizer rates were applied to plots of different rotations to bring up the nitrogen (N) levels to 80 lbs N/acre. Fertilizer rates ranged from 30 to 70 lbs N/acre. Winter pea ('Spector') for rotation 7 was direct-seeded at the rate of 7 peas/ft^2 (85 lbs/acre) on October 15, 2005. Granular inoculant was applied with the seed at the rate of 57 grams/1,000 ft of row. About 10 lbs N/acre was applied at seeding. Spring barley ('Camas') for rotations 5 and 6 was direct-seeded on April 12 and 13 at 22 seeds/ft^2. Spring wheat ('Louise') for rotation 4 was direct-seeded on March 30. Spring cereals received about 20 lbs N/acre. Using the Fabro® drill, seed was placed at a depth of 1 inch and fertilizer at 3 inches. For the two Flex crop treatments (rotation 8), 'Tilney' mustard and canola were direct-seeded at 10 lbs/acre using the Fabro® drill. Each phase of each rotation is present each year. Data on plant stand, phenology, weeds, and diseases were collected. At maturity, plots were harvested using a commercial combine with an 18-ft header. The 18-ft swath was taken right in the center of the 48-ft-wide plot. Grain was weighed using a weigh-wagon to determine yield per treatment.

Soil water measurements were taken throughout the growing season using a PR2® probe (Delta-T Devices Ltd. Cambridge, England). The probe senses the soil moisture content at 4-, 8-, 16-, 24-, and 40-inch depths by responding to dielectric properties of the soil. Readings were made on two access tubes in each plot. At each reading, two measurements were taken, each time with the probe rotated to a different direction.

Center of Sustainability

The experiment is located at the William Jepsen farm near Heppner, Oregon. In the past 5 years the Center of Sustainability (COS) has evaluated cropping systems that are similar to the cropping systems at Moro (Table 1). The COS site receives similar crop-year precipitation to Moro (11 inches), but its soil is shallower (2 ft deep) than the Moro site (greater than 4 ft deep). This makes it possible to effectively determine the influence of soil depth on the alternate cropping systems. The cropping systems being evaluated at COS were modified in the 2003-2004 season to match most of the treatments at Moro. Data collection is the same as at Moro, but the experiment is not replicated. However, the experiment has very large plots that measure 80 ft by 900 ft and it may be possible to split the plots and add at least one replication. In the meantime, data will be analyzed using statistical methods for unreplicated studies (Perrett and Higgins 2006).

Table 2. Cropping and tillage systems under evaluation at the Center of Sustainability (COS) study at Bill Jepsen's farm near Heppner, Oregon.

Treatment/rotation	Description
1	Conventional winter wheat/conventional fallow
2	Winter wheat/chemical fallow–direct seeding
3	Continuous spring barley–direct seeding
4	Continuous spring wheat-direct seeding
5	Continuous spring DNS–direct seeding
6	Continuous winter wheat-direct seeding
7	Spring barley/mustard/spring wheat–direct seeding
8	Winter wheat/mustard/chemical fallow–direct seeding
9a	Flex crop
9b	Flex crop

Results and Discussion

Data on grain yield and pests that were collected in the 2005-2006 crop year are discussed in this report.

CBARC, Moro

Soil water measurements

Soil moisture content measurements (average of whole 40-inch profile) for each treatment, from March 3, 2006, to August 18, 2006, are shown in Figure 1. As expected, fallow treatments had the highest amount of moisture throughout this period. The winter wheat after chemical fallow treatment (rotation 2) had the lowest soil moisture from the start of the measurements to the end. Surprisingly, moisture content of plots under continuous winter wheat was higher than all cropped treatments beginning in June onwards. At the last measurement, the moisture of this treatment was 16 percent compared to 9 percent under winter wheat following chemical fallow. A closer look at soil water distribution in the 40-inch profile of this treatment (data not shown) shows that wheat in this treatment used water mostly from the top 8 inches and did not use as much water from the lower depths when compared to the other cropped treatments. This indicated that other factors were preventing wheat from extracting water at deeper profiles.

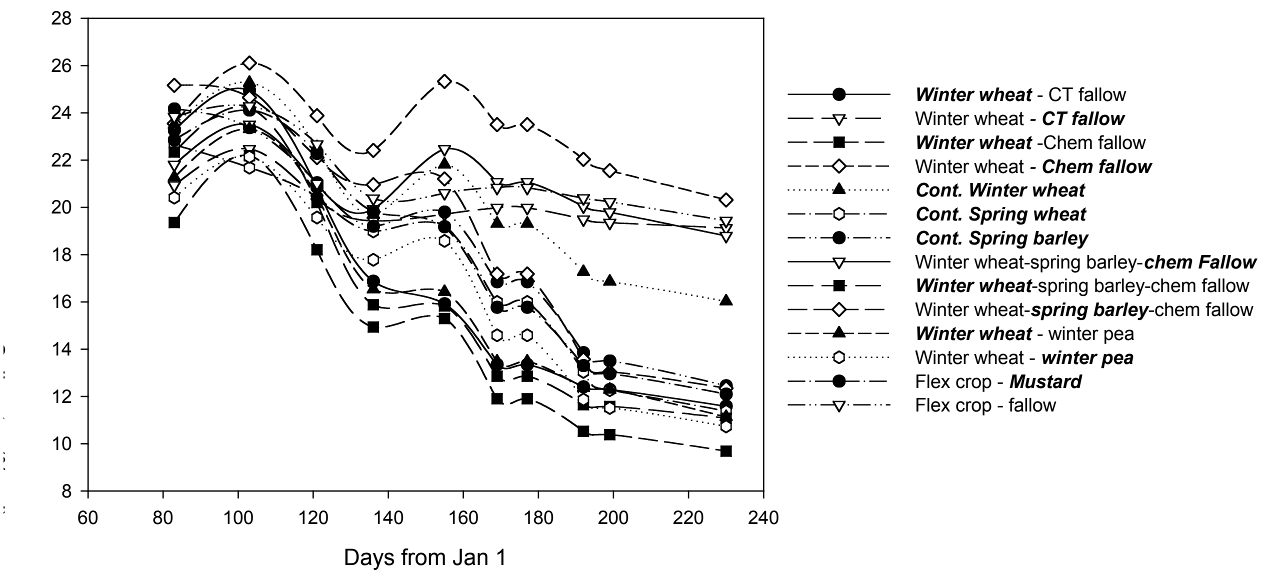

Figure 1. Average soil water content under all rotations in the 0- to 40-inch depth profile from March to August, 2006, at Columbia Basin Agricultural Research Center, Moro, Oregon.

Weeds

The weeds team evaluated downy brome (*Bromus tectorum*) and broadleaf weed control in the cropping systems under study. Weed plant counts were taken in March and May of each year. At the beginning of the study there were no significant differences in weed populations. Results in 2006 indicated that downy brome populations had increased in direct-seeded winter wheat, with a significant increase in recrop direct-seeded winter wheat (Table 3). These treatments were not treated for grass control in 2006. Downy brome populations in all other treatments declined to low levels (fewer than 0.5 plants/ft^2). All broadleaf weed species population numbers have declined in all treatments to fewer than 0.5 plants/ft^2.

Table 3. Downy brome populations in different cropping systems after herbicide treatment, Moro Long-term Experiment, 2004, 2005, 2006.

		Downey brome (plants/m^2)		
Treatment	Rotation	5/5/04	5/3/05	5/19/06
1[1]	1	5	2	6
2	1	0	1	0
3	2	4	2	12
4	2	0	2	0
5	3	8	11	20
6	4	0	0	0
7	5	0	0	2
8	6	8	0	0
9	6	0	0	0
10	6	0	5	0
11	7	8	0	8
12	7	2	1	0
13	8	0	0	0
14[3]	8	0	0	0
$LSD_{0.05}$		7	4	8

[1] Treatments No. 1, 3, 5, 9 and 11 did not receive a grass herbicide before May 19, 2006. Flex crop in 2004 was spring wheat, in 2005 it was spring barley, and in 2006 it was mustard.
[3] Treatment no.14 was plowed up in 2006.

Diseases

Diseases in fall- and spring-planted plots were assessed during late March and mid-June, respectively. Samplings consisted of 20 to 40 plants plus intact roots collected over the length of each plot, washing soil from the roots, and scoring each root system for incidence (percent plants) and severity (qualitative rating scale) of diseases such as Fusarium foot rot, take-all, and Rhizoctonia root rot. Plants were also examined for the presence or level of damage by other diseases and insect pests. Soil samples (about 20 cores/plot; 1-inch diameter by 12-inch depth) were collected in early April and sent to Western Laboratories (Parma, ID) for quantification of plant-parasitic nematode genera.

March 29, 2006 sampling

All three replicates of five winter wheat and one winter pea treatment were sampled. The incidence of lesions on subcrown internodes, caused by Fusarium crown rot, was high (30 percent) only on winter wheat following the traditional cultivated summer fallow. The severity indices for subcrown internode lesions also appeared higher in the conventional winter wheat-summer fallow rotation than in other treatments but this apparent difference was not statistically significant. There were also no statistical differences among treatments for the incidence and severity of Rhizoctonia root rot, take-all, and Fusarium crown rot symptoms on seminal roots. On crown roots, symptoms of the three root diseases occurred mostly in the conventionally tilled winter wheat-summer fallow rotation, but differences were not statistically significant at P = 0.05. Most of the important observations reported for fall-planted crops during this sampling in 2006 were consistent with observations reported 1 year earlier, during March 2005.

Cotyledons of winter pea that was rotated with winter wheat had a very minor occurrence of a blackening caused by *Thielaviopsis basicola*. A complex of *Rhizoctonia* and *Pythium* species caused lesions to occur on a high percentage (70 percent) of tap roots but the severity of lesion development was low to moderate. As during 2005, vascular browning caused by Fusarium wilt was not detected.

June 15, 2006 sampling

All replicates of one spring wheat, two spring barley, and one spring mustard (flex crop) treatments were sampled. No diseases were observed on spring mustard. The incidence of diseases on subcrown internodes and seminal roots of wheat and barley did not differ significantly among treatments. Nevertheless, there was a distinct trend for higher incidence of Rhizoctonia root rot on the barley than wheat, and an opposite trend for incidence of take-all. Rhizoctonia root rot was the only disease of importance on the coronal root system, and was significantly greater on barley than wheat.

Nematode observations for samples collected on April 4, 2006

Root-lesion nematodes were the primary plant-parasitic species detected in the soil samples collected shortly after spring crops were planted. Although not significant at P = 0.05, the population of root-lesion nematodes was considerably higher in rotations including winter wheat than other crops. Populations of root-lesion nematodes approximated or exceeded the estimated threshold for economic damage (900/lb of soil) in five treatments, each of which included winter wheat as a current or recent crop. These treatments were numbered 1 (winter wheat rotated with conventional summer fallow), 5 (annual direct-drill winter wheat), 10 (spring barley recently planted in soil following a winter wheat crop), 11 (winter wheat following winter pea), and 12 (winter pea following winter wheat). Populations were lower where winter wheat followed chemical fallow after spring barley (treatment 9). High populations under winter pea likely reflected a residually high population from the previous crop of winter wheat.

It appears probable that elevated populations of root-lesion nematodes are occurring following winter wheat and the “summer-fallow winter” because of the functional monoculture for these winter wheat production systems; e.g., winter wheat is produced for 10 or 11 months of a 24-month cycle and volunteer wheat and winter-annual grass weeds (downy brome) are allowed to grow for up to 5 months during the 14-month summer-fallow phase of the rotation. Root-lesion nematodes are apparently being amplified during both phases of this functional monoculture, as compared to a more restricted period of living plants in annual spring wheat systems.

Spring barley continues to suppress populations of these nematodes. Specifically, root-lesion nematode populations tended to be lower in continuous barley than in the two treatments where spring or winter wheat was produced annually.

Grain yield

The 2005-2006 crop year was the third cropping season of this experiment. One more year is required to complete a full cycle for 2-year rotations and 3 more years are required to complete a full cycle for 3-year rotations. Grain yields of winter wheat, spring wheat, spring barley, and winter pea obtained in the 2005-2006 crop year are shown in Table 4. This crop year was much wetter (16.92 inches) than the 2004-2005 crop year (7.76 inches), resulting in higher yields. Continuous spring barley produced the highest yield but the spring barley yields were not significantly different from yield produced by winter wheat following conventional fallow or winter wheat after chemical fallow in a 3-year rotation with spring barley. The barley yield was, however, significantly higher than the yield of winter wheat after chemical fallow (2-year rotation). Yield from annual crops was significantly lower than yield of wheat following fallow or continuous spring barley. Continuous winter wheat produced the lowest yield. At first we suspected that downy brome, whose populations were highest in this treatment, competed with wheat for water and resulted in low wheat yields. However, soil moisture data showed that this treatment had more residual moisture than all cropped treatments, particularly in soil zones below 8 inches. This suggested that there were other factors that influenced yield of continuous winter wheat. High incidences of Fusarium crown rot lesions and root-lesion nematodes in this treatment could have reduced yields. Fertility could be another factor; downy brome, whose populations were high in this treatment, probably competed with wheat for nutrients.

Table 4. Grain yield of winter wheat, spring wheat, spring barley, and winter peas under different cropping systems at Columbia Basin Agricultural Research Center, Moro, Oregon, 2005.

Rotation	**Grain yield (bu/acre)**			
Annual cropping	2003-2004	2004-05	2005-06	2-yr avg
Continuous *winter wheat*	50.9ab	10.6c	18.4d	14.5de
Continuous *spring wheat*	39.4c	10.1c	37.7bc	23.9de
Continuous *spring barley*	54.3a	11.6c	63.6a	37.6bc
2-year rotations				
Conventional fallow-*Winter wheat*	48.1b	58.0a	58.6a	58.3a
Chemfallow-*Winter wheat*	48.8ab	52.9ab	45.9b	49.4ab
Winter wheat-*winter pea*		9.1c	17.1d	13.1e
Winter pea-*winter wheat*	48.5ab	40.5ab	32.8c	36.6c
3-year rotations				
Chemfallow-*winter wheat*-spring barley	50.1ab	63.2a	56.9a	60.1a
Winter wheat-*spring barley*-chemfallow	40.6c	12.8c	58.0a	35.4cd
Flex crop				
Spring barley-*spring wheat*	37.0c	12.9c	-	
Spring wheat-*spring barley*	41.8c	13.8bc	-	
Spring wheat-*mustard*	-	-	13.6d	
Precipitation (mm)	11.9	7.8	16.9	

†All plots are direct seeded except the conventional fallow treatments (rotation 1).

On average (2004-2005 and 2005-2006), wheat following fallow in a 3-year rotation with spring barley produced the highest yield, although this yield was not significantly different from yield of wheat after conventional or chemical fallow. Data on nematodes indicated that continuous spring barley suppressed nematodes. In rotations involving annual cropping, continuous spring barley produced the highest yields, followed by winter wheat after winter pea. Continuous winter wheat produced the lowest yields over the 2 crop years. The initial yields of the experiment (2003-2004 crop year) were not included in the averages because all crops followed spring wheat

Center of Sustainability, Heppner

Grain yield

Grain yields produced in the 2002-2003 to the 2005-2006 crop years are shown in Table 5. Results exclude 3-year rotations. Under continuous cropping, spring barley produced the highest yields followed by winter wheat. The average yields of continuous winter wheat do not reflect the true picture because the wheat was planted in an almost fallow situation following a 30 lb/acre lentil crop in the 2002-2003 crop year. Continuous spring wheat produced the lowest yields. Winter wheat after either conventional fallow or chemical fallow produced much higher yields than continuous crops but annualized yields were lower than continuous spring barley. The experiments will run for 3 more crop years for all rotations to complete a full cycle.

Table 5. Grain yield of winter wheat, spring wheat, and spring barley under different cropping systems at the Center of Sustainability, Heppner, Oregon.

	Continuous cropping				2-year rotations		
Rotation	3	4	5	6	1	2	Precip.
Year	Cont. S. Barley	Cont. S. Wheat	Cont. DNS	Cont. W. Wheat	W. Wheat after Conv. fallow	W. Wheat after Chem. fallow	Sept-June
	------------------------------------ bu/acre					-------------------------------------	--- in ---
2002-2003	24	14	12	30 (Lentil)	19	25	10.6
2003-2004	47	32	33	42	44	46	11.6
2004-2005	42	16	23	25	68	71	9.4
2005-2006	52	29	28	34	47	56	14.5
Mean[1]	**47**	**26**	**28**	**34**	**53**	**58**	**11.9**
Annual	**47**	**26**	**28**	**34**	**27**	**29**	

[1] 2003-2004 to 2005-2006 crop-year mean.

Diseases

Nematode populations were evaluated in soil samples collected during 2005 and 2006 from treatments 112 (direct-drill hard red spring wheat [HRSW]), 113 (direct-drill soft white spring wheat [SWSW]), 114 (direct-drill spring barley [SB]), 115 (2005: conventional fallow in a rotation with soft white winter wheat [SWWW]; 2006: SWWW following fallow), 116 (2005: SWWW in a rotation with conventional fallow; 2006: fallow following SWWW), and 111 (2005: chemical fallow in a rotation with SWWW; 2006: SWWW following chem-fallow). Samples were collected with a Giddings hydraulic soil sampler (Giddings Machine Co., Windsor, CO). Five samples were collected for each of the six COS treatments. Each field sample was a composite of two cores taken 3 ft apart. Soil cores were separated into depth intervals of 0-6, 6-12, 12-18, 18-24, 24-36, and 36-48 inches. Root-lesion nematodes were extracted from the 180 samples; 6 treatments by 5 sites/treatment by 6 depth intervals/site. Populations for each depth increment were determined and averaged among the five sampling sites/plot.

For shallow samples (0 to 6 inches) approximating the depth sampled using small manually inserted soil probes, populations of *Pratylenchus neglectus* (root-lesion nematode) exceeded the economic threshold level in two of six COS treatments during 2005 and in five of six treatments sampled during 2006. During 2005, populations exceeded the economic threshold level of 900 *Pratylenchus*/lb of soil in treatments where SWWW was rotated with either conventional summer fallow or chemical summer fallow. Moderately high populations nearly equaling the economic threshold level were also detected in two direct-drill annual spring wheat treatments planted to either SWSW or HRSW (Dark Northern Spring (DNS)). During 2006, *P. neglectus* populations were less than half the economic threshold value in the annual spring barley treatment and exceeded the threshold in the other five treatments. The latter findings were identical to data bulked over the full 24-inch soil depth and combined over years 2005 and 2006; namely the population of *P. neglectus* in the spring barley treatment (498/lb of soil) was much lower than for annual HRSW (1,388/lb), annual SWSW (1,432/lb), SWWW/chem fallow (2,056/lb), and SWWW/conventional fallow (1,599/lb for in-crop phase and 1,680/lb for fallow phase).

During 2005 grain yield for direct-drill HRSW (cv 'Jefferson'; COS treatment no. 112) was 41 percent greater than for an adjacent treatment of direct-drill SWSW (cv 'Alpowa'; treatment no. 113). Mean populations of *P. neglectus* were near the estimated economic threshold level in both treatments. A nematicide experiment was therefore placed into the two COS treatments during 2006 to determine if root-lesion nematode could be responsible for the yield difference observed during 2005. Nematicide treatments consisted of Temik® (Bayer CropScience)-treated and untreated control plots replicated six times in the SWSW and HRSW plantings. Each plot measured 11 by 50 ft and consisted of either no treatment or application of Temik 15G before planting. The nematicide was drilled into soil at 3-inch depth and 25 lb/acre. During 2006, root-lesion nematode populations in both plantings were above the estimated threshold for causing economic damage. Grain yields differed between nematicide treatments (P = 0.017) but not between varieties (P = 0.177). Temik-treated plots averaged 1.6 bu/acre more than for untreated plots ($LSD_{0.05}$ = 1.3). The yields were 31.7 and 30.4 bu/acre for Temik-treated and untreated 'Alpowa', and 32.9 and 30.9 bu/acre for Temik-treated and untreated 'Jefferson'. We concluded that *P. neglectus* suppressed yields of both varieties equally during 2006 and were unlikely to have been responsible for the strong yield differential between varieties during 2005. It was of interest, however, that depth profile samples averaged over both years indicated that *P. neglectus* populations at the 12- to 24-inch depth increment were more than twice as high for the 'Alpowa' than 'Jefferson' treatment, and that the opposite relationship occurred in the 0- to 12-inch depth increment. Crop-year precipitation was 9.4 inches during 2005 and 14.5 inches during 2006 (Table 5). It is possible that the higher population of *P. neglectus* deep in the soil profile under 'Alpowa', as compared to 'Jefferson', may have imposed a higher level of drought stress on

'Alpowa' than 'Jefferson' during the drier (2005) but not the wetter year (2006), leading to a yield difference for these varieties during 2005 but not 2006 (Table 5).

References

Perrett, J.J., and J.J. Higgins. 2006. A method for analyzing unreplicated agricultural experiments. Crop Science 46:2482-2485.