LONG-TERM EXPERIMENTS AT CBARC-MORO AND CENTER OF SUSTAINABILITY, HEPPNER, 2005

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AbstractA set of long-term experiments (LTEs) was established on a 28-acre site at the Columbia Basin Agricultural Research Center (CBARC), at Moro, Oregon and at the Center of Sustainability Farm (COS) near Heppner, Oregon in the fall of 2003. The second cropping season of the experiments was completed. Four more crop-years are required for all crop rotations to complete a full cycle. This report covers the 2004-2005 crop-year period. *CBARC, Moro LTE*: Winter wheat following summer fallow (conventional or chemical) produced significantly ($P < 0.05$) higher grain yields than annual cropping systems involving winter wheat, spring wheat, spring barley, and winter pea following winter wheat. Downy brome populations increased in direct-seeded winter wheat and the annual direct-seeded winter wheat had the greatest increase. Rotation and herbicide applications were effective at reducing prostrate knotweed. Prickly lettuce and tumble mustard increased; tumble mustard increased the most in spring crops. Root diseases caused by *Fusarium, Rhizoctonia, Pythium*, and root-lesion nematodes (*Pratylenchus thornei* and *P. neglectus*) varied between treatments. *COS LTE*: Continuous spring barley produced the highest grain yields followed by winter wheat following either conventional or chemical fallow. The lowest yield was obtained from continuous Alpowa spring wheat that was very susceptible to root-lesion nematodes.

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 objective of the experiment phase is to establish and maintain long-term experiments that compare the conventional wheat-fallow system with alternate cropping systems with crop management practices such as direct seeding that 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. The research is targeted for Agronomic Zones 4 and 5 in north-central 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 two crop-years so far (2003-

2004 and 2004-2005). The soil is a Walla Walla silt loam (coarse-silty, mixed, superactive, mesic Typic Haploxeroll) and is more than 4 ft deep. From 1984 to 2004, the station received an average of 10.7 inches of annual precipitation, with a range of 5.9 to 16.8 inches. Rainfall and soil at the station is 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, which brings the minimum total experimental area to 13.88 acres. Agronomic practices (planting date, planting rate, and fertilizer, herbicide, seed-treatment fungicide, and insecticide applications) are based on the treatment in question. Direct seeding is conducted using the Fabro® drill purchased with assistance from the Sherman Station Endowment Fund (Growers) in Moro.

Field operations: Winter wheat (Tubbs) for conventional wheat-summer fallow treatment was seeded on October 7, 2004 using the HZ drill. Tubbs, for chemical fallow treatment, was direct-seeded at 20 seeds/ft^2 (85 lbs/acre) at a depth of 1 inch on October 22, 2004 and for continuous winter wheat and winter wheat/winter pea treatments on October 25, 2004 using a Fabro drill. Preplant soil analysis results revealed adequate N levels (~80 lbs N/acre in the top 4 ft) and only 30 lbs N/acre starter fertilizer was applied. Winter pea (PS9430706) for the wheat/winter pea treatment was direct-seeded at the rate of 7 peas/ft^2 (101 lbs/acre) on October 26, 2004. Granular inoculant was applied with the seed at the rate of 57 g/1,000 ft and about 10 lbs N/acre was applied at seeding. Spring barley (Camas) for the continuous spring barley and winter wheat/spring barley treatments was direct-seeded on March 17. Spring barley for treatment 8 (flex crop) was seeded on March 21, 2005. Spring wheat (Zak) for continuous spring wheat treatment was direct-seeded on March 18 and for treatment 8 (flex crop) on March 21, 2005. Spring cereals were seeded at 20 seeds/ft^2 and received about 10 lbs N/acre. The Fabro drill placed seed at a depth of 1 inch and fertilizer at 3 inches. Each phase of each rotation is present each year.

Table 1. Cropping systems under evaluation at the Sherman County Experiment Station, Moro, Oregon.

Cropping systems	Description
1, 2	Winter wheat-fallow/Conventional tillage
3, 4	Winter wheat-chem. fallow/Direct seeding
5	Continuous winter wheat/Direct seeding
6	Continuous spring wheat/Direct seeding
7	Continuous spring barley/Direct seeding
8, 9, 10	Winter wheat-spring barley-chem. fallow/Direct seeding
11, 12	Winter wheat-winter pea/Direct seeding
13, 14	Flex crop (2)/Conventional tillage/Direct seeding

Data Collection

Soil fertility

Data to establish baseline information were collected before seeding in 2003. A representative soil sample was collected at 12-inch intervals to 60 inches or to a restricting layer using a Giddings® probe at 5 locations in each plot. Soil sampling will be repeated during the sixth year. The samples were analyzed for pH, OM, P, K, NO_3, NH_4, and SO_4 in the 0- to 12-inch samples, NO_3 and SO_4 in the 12- to 24-inch samples, and NO_3 in the 24- to 60-inch samples. In the past crop year, the soil was analyzed for NO_3, NH_4, and SO_4 in the first 12 inches and NO_3 in the 12- to 48-inch samples to determine fertilizer recommendations.

Agronomic and phenological data

Basic data on the timing of agronomic practices, dates of plant emergence, plant counts, anthesis, and maturity, biomass, yield, diseases, weeds, insect pests, soil moisture, and erosion were collected. Plants were considered emerged when more than 50 percent of the plot had emerged plants. Plants were counted in 6, 3-ft quadrats in the sampling areas. The plot was considered to have flowered or matured when more than 50 percent of the plants had flowered or matured. Total plant biomass from at least 6, 3-ft quadrats was collected from the sampling areas for the determination of harvest index. The rest of the plot area was harvested by a commercial-size combine to obtain grain yield. Grain weight was measured using a weigh wagon.

Pests

Diseases in fall- and spring-planted plots were assessed during March and May, respectively. All samplings involved collecting 20 to 40 plants over the length of each plot, washing soil from roots, and scoring each plant individually 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 of other diseases and insect pests. Soil samples (about 20 cores per plot; 1-inch diameter by 6-inch depth) were also collected during March and sent to Western Laboratories (Parma, ID) for quantification of plant-parasitic nematode genera. Data were examined for the presence of replicate (slope position or location) effects as well as for differences among treatments.

The Weeds team evaluated downy brome (*Bromus tectorum*) and broadleaf weed control in the cropping systems under study. Weed plant counts were taken on March 29 and May 5, 2004 and May 3, 2005. Weeds were counted in 5 randomly placed 0.5-m^2 quadrats per plot.

Soil moisture, water infiltration and erosion, and soil physical properties

We were not able to acquire a neutron probe for soil water measurements. We have since acquired a PR2 probe® (Delta-T Devices, Cambridge, England) that measures soil moisture by dielectric methods. About two to three access tubes/plot will be installed in the spring of 2006.

We will also use $ECH_2O^{®}$ moisture probes (Decagon Devices, Inc., Pullman, WA) in selected plots to obtain continuous soil moisture readings. Water infiltration, earthworm populations, and aggregate stability were measured at the start of the experiments in 2003 and will be repeated in the sixth year. Erosion has not yet been measured.

Soil microbial assays
Microbial population and diversity has not yet been determined but we expect the measurement to take place in the sixth year.

Production economics
We tracked and recorded the inputs and outputs of each cropping system for economic analyses. The most economic system will be determined. We will enlist the collaboration of agricultural economists from Oregon State University, Washington State University, the University of Idaho, or from the growers to carry out the economic analysis.

Weather data
Data on precipitation, soil temperature, and air temperature were collected.

Center of Sustainability
The Center of Sustainability (COS) that was a Monsanto project from 1999 to 2003 was incorporated into this project in 2003. The experiment is located at the William Jepsen farm in Heppner, Oregon. In the past 5 years, COS has evaluated eight cropping systems (Table 2) that are similar to the proposed cropping systems at Moro (Table 1). A few rotations were changed to match rotations at Moro. The effects of the alternate cropping systems (direct seeding) on soil physical and chemical properties are beginning to show and it is for this reason that the study should continue. The COS site is unique in that it receives similar crop-year precipitation (11-13 inches) to Moro (10.7 inches), but it has shallower soil depth (2 ft) than the Moro site (>4 ft). This makes it possible to effectively determine the influence of soil depth on the alternate cropping systems. The cropping systems being evaluated at the COS site are shown in Table 2. 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 valid statistical methods for unreplicated studies (Perrett 2004).

Additionally, populations of lesion nematodes throughout the soil profile were determined by collecting deep cores from six of the COS experimental treatments. Details of the sampling method are presented in another paper in this report (see the paper by Sheedy, Smiley, and Easley). Briefly, samples were collected from six plots, including five shown in Table 2; both phases of conventionally tilled winter wheat-fallow rotation (SWWW-CVF = wheat phase, and SWWW-CVF = fallow phase, no. 1 in Table 2), soft-white winter wheat-chemical fallow rotation (SWWW-CHF, no. 2), annual spring barley (SB, no. 3), annual soft-white spring wheat (SWSW, no. 4), and annual hard-red spring wheat (DNS, no. 5). Samples were collected with a Giddings hydraulic soil sampler. Five samples were collected for each of the six plots. 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 quantified for each of the 180 samples; 6 plots by 5 sites/plot by 6 depth intervals/site. Populations for each depth interval were averaged among the five sampling sites/plot.

Table 2. Cropping and tillage systems under evaluation at the Center of Sustainability Study at Bill Jepsen's farm in 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 Dark Northern Spring Wheat (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 were collected in the 2004-2005 crop-year and are discussed in this report.

CBARC, Moro

Grain yield

The 2004-2005 crop-year was the second cropping season of this experiment. Two more years are required to complete a full cycle for 2-year rotations and 4 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 2004-2005 crop year are shown in Table 3. This crop-year was drier (7.88 inches) than the 2003-2004 crop-year (11.91 inches). Winter wheat following conventional and chemical fallow produced significantly ($P < 0.05$) higher grain yields than all annual crops. Lower yields in these annual cropping systems were attributed to low soil moisture and high incidences of weeds. Winter wheat following winter peas produced higher grain yields than other annual crops probably because of more available soil moisture. The previous winter pea crop was very poor and did not use much of the available soil water. There were no significant differences in grain yield between all the other annual cropping systems involving winter wheat, spring wheat, and spring barley

Pests

Disease (*Rhizoctonia* root rot, take-all, and *Fusarium* crown rot) severity was very low. Compared to winter wheat, root-lesion and stunt nematode populations were elevated under winter pea. Root-lesion nematode populations in soil tended to be lower following barley than winter or spring wheat. Lowest populations of root-lesion nematodes occurred in soils that were either fallow the previous year or were planted annually to spring barley.

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Table 3. Grain yield of winter wheat, spring wheat, spring barley, and winter peas under different cropping systems for the 2004-2005 crop-year at Columbia Basin Agricultural Research Center, Moro, Oregon.

Rotation[a]					
		2004-2005	2005-2006	**2004-2005 Yield**	
Treatment	2003-2004 crop	**crop**	crop	**(lbs/acre)**	**bu/acre**
1	WW-CT	**Fallow-CT**	WW-CT	-	-
2	Fallow-CT	**WW-CT**	Fallow-CT	**3,273**	**54**
3	WW-DS	**Chem fallow**	WW-DS	-	-
4	Chem fallow	**WW-DS**	Chem fallow	**3,011**	**50**
5	WW-DS	**WW-DS**	WW-DS	**576**	**9**
6	SW-DS	**SW-DS**	SW-DS	**530**	**9**
7	SB-DS	**SB-DS**	SB-DS	**553**	**11**
8	WW-DS	**SB-DS**	Chem fallow	**622**	**13**
9	SB-DS	**Chem fallow**	WW-DS	-	-
10	Chem fallow	**WW-DS**	SB-DS	**3,503**	**58**
11	WW-DS	**WP-DS**	WW-DS	**507**	-
12	WP-DS	**WW-DS**	WP-DS	**2,282**	**38**
13	Flex (SB)	**Flex (SW)**	Flex	**691**	**11**
14	Flex (SW)	**Flex (SB)**	Flex	**668**	**14**
$LSD_{0.05}$				**1,003**	**17**

[a] All plots were direct seeded except the conventional fallow treatments (1 and 2); Chem = chemical; CT = conventional tillage; DS = direct seeding; Flex-crop = cropping system decided based on prevailing soil moisture conditions and grain price; SB = spring barley; SW = spring wheat; WP = winter pea; WW = winter wheat.

Downy brome populations increased in direct-seeded winter wheat, with the greatest increase in recrop winter wheat. Rotation and herbicide applications were effective at reducing prostrate knotweed. Prickly lettuce and tumble mustard both increased, with tumble mustard increasing the most in spring crops

Center of Sustainability, Heppner

Grain yield

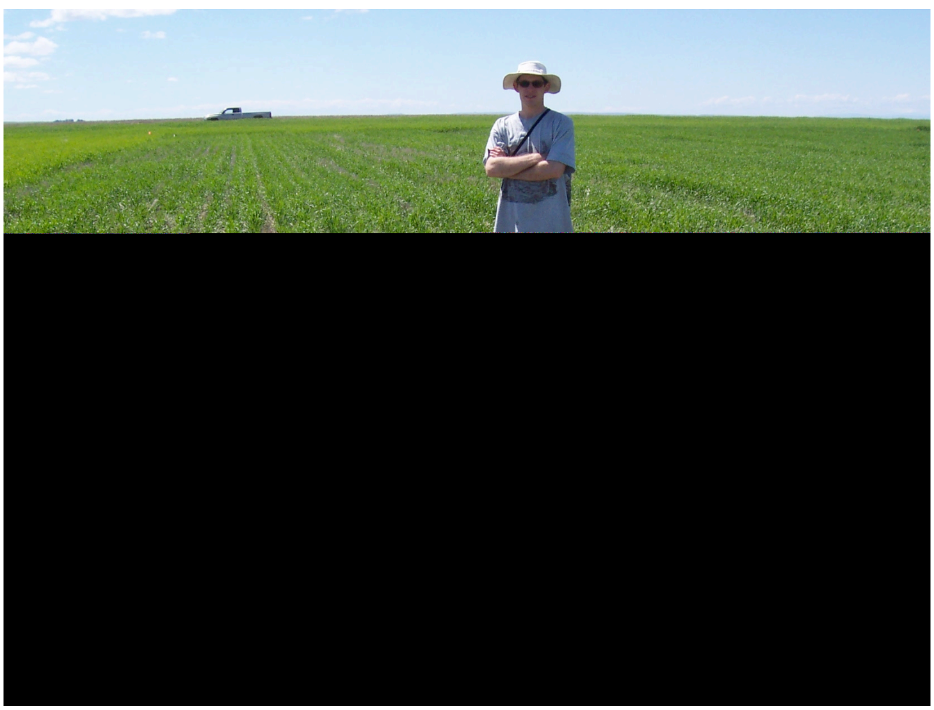
Grain yields produced in the 2002-2003 to the 2004-2005 crop-years are shown in Table 4. Monsanto rotations ended in the 2002-2003 crop-year and the new rotations were initiated from the 2003-2004 crop-year. Results (Table 4) exclude 3-year rotations. Under continuous cropping, spring barley (Steptoe) produced the highest yields followed by winter wheat (Stephens) and Dark Northern spring wheat (DNS cv. Jefferson). The average yields of continuous winter wheat do not reflect the true picture because the wheat was planted under almost fallow conditions following a 30-lb/acre lentil crop in 2002-2003. Continuous spring wheat (Alpowa) produced the lowest yields. Winter wheat after either conventional fallow or chemical fallow produced much higher yields than the continuous crops but annualized yields were lower than continuous spring barley. The experiments will run for another 4 crop-years for all rotations to complete a full cycle.

Table 4. Grain yield (lb/acre) of winter wheat, spring wheat, and spring barley under different cropping systems at the Center of Sustainability, Moro, Oregon, 2004-2005 crop-year.

	Winter wheat following fallow		Continuous cropping				
Rotation	1	2	3	4	5	6	Precip (in)
Year	Conventional fallow	Chemical fallow	Spring barley	Spring wheat	DNS wheat	Winter wheat	Sept-June
2002-03	1,146	1,518	1,138	810	744	30 [a]	10.57
2003-04	2,664	2,778	2,275	1,926	1,974	2,538	11.62
2004-05	4,074	4,266	2,000	972	1,368	1,482	9.42
Mean	**3,369**	**3,522**	**2,138**	**1,449**	**1,671**	**2,010**	**10.52**
Annualized	**1,685**	**1,761**	**2,138**	**1,449**	**1,671**	**2,010**	

[a] Lentil yield

Figure 1. Center of Sustainability experiment showing plot with bare patches caused by pests.



Pests

Bare or stunted patches were observed in the last 2 crop-years (Fig. 1). Mr. Jepsen collected shallow samples of roots and soil from good areas (healthy areas) and bad areas (stunted crop or bare patches) and Dr. Richard Smiley's plant pathology staff analyzed the samples for diseases and nematodes. The data for nematode populations and *Rhizoctonia* root rot are shown in Table 5. Soil in the continuous spring wheat (Alpowa) had high numbers of *P. neglectus*. Stained roots indicated that the wheat root cortex was entirely packed with nematodes. High numbers of nematodes in Alpowa roots undoubtedly contributed to an overall reduction in yield for this crop. There were very few symptoms of *Rhizoctonia* root rot in the Alpowa. There was some take-all, but not enough to cause the stunting and uneven growth shown in the photograph (Fig. 1)

Populations of *P. neglectus* in the continuous barley (Steptoe) were much lower than in continuous Alpowa. Soils from the patches of stunted Steptoe had higher nematode populations than soils from the more healthy part of the field. Also, the roots of stunted Steptoe plants were heavily damaged by *Rhizoctonia* root rot. *Rhizoctonia* stunting was reduced in good patches but elevated in bad patches. *Rhizoctonia* root rot appeared to be the primary constraint to yield in annual spring barley.

Populations of *P. neglectus* were much higher in the stunted mustard (Tilney) than in the healthy plants. Sampling of soil in nearby production fields also revealed higher populations of *P. neglectus* following mustard compared to wheat (unpublished data). In the plots there were also high numbers of other plant-parasitic nematode species in the mustard. *Rhizoctonia* root rot was present at a very low level of severity but there was little evidence that this or other fungal diseases caused any damage to the mustard.

Table 5. Nematodes and *Rhizoctonia* root rot in samples collected from apparently "healthy" and from stunted patches of crops grown at the Center of Sustainability experiment, 2004-2005 crop-year.

	Alpowa wheat		Steptoe barley		Tilney mustard	
Parameter [a]	Healthy	Stunted	Healthy	Stunted	Healthy	Stunted
PT	0	0	0	0	0	78
PN	2,287	2,556	340	554	38	586
OPP	604	426	170	277	647	742
NPP	9,105	7,028	10,080	15,584	10,125	16,092
RRR	low	low	low	mod-severe	low	low

[a]PT = *Pratylenchus thornei*/lb dry soil; PN = *Pratylenchus neglectus*/lb dry soil; OPP = other plant parasitic nematodes/lb dry soil (e.g., parasites other than *Pratylenchus* spp.); NPP = non-plant-parasitic nematodes/lb dry soil; RRR = *Rhizoctonia* root rot severity

While single-site samples from shallow depth in apparently healthy and stunted patches provided information about the specific sites sampled, the systematic profile-depth samples collected at multiple sites within each plot provided a broader perspective of the potential for *P. neglectus* to affect overall yield. The depth samples showed that *P. neglectus* was distributed to at least 24-inch depth in all treatments and to 36-inch depth in several treatments (Table 6). When samples were collected on June 1, total *P. neglectus* populations through the profile were greater in the fallow phase than in the in-crop phase of the soft-white winter wheat-conventionally tilled summer fallow system. The high numbers in the fallow appeared to indicate that the nematodes multiplied efficiently in roots of winter wheat harvested during August 2004 and survived until samples were collected in June 2005. Populations that existed after the winter wheat matured possibly increased further in volunteer wheat and cheatgrass plants that emerged in the stubble during early winter and were not sprayed with glyphosate until March 3 and cultivated (chisel plow) on May 7. Since *Pratylenchus* populations are likely to decline slowly during the period of cultivated fallow, from May through October, the lower population measured in winter wheat on June 1, compared to the summer fallow, appears to indicate that the populations in winter wheat had not yet reached the peak when sampled before heading.

In annual spring crops, the total population in the profile was greater in the soft-white spring wheat (Alpowa) than in hard-red spring wheat (Jefferson) or spring barley (Steptoe). The estimated economic threshold limit (ETL), above which root-lesion nematodes cause economic loss, is currently considered to be about 900 *P. neglectus*/lb of soil. Populations were higher than the estimated ETL in the summer fallow following winter wheat, and approached this limit at selected depths in the Alpowa and Jefferson wheat plots. Individual "hot spots" within all plots were likely to have been higher than the reported values derived from averages of 10 cores collected from each plot; 5 sampling sites and 2 cores per "sample". We concluded that lesion nematodes were likely to have influenced yields of wheat but not barley, and that *Rhizoctonia* root rot appeared to be the primary yield-limiting disease for barley.

Table 6. Vertical distribution of root-lesion nematodes (*Pratylenchus neglectus*/lb of soil) in six plots of the Center of Sustainability experiment, 2004-2005 crop year; treatments are described in Table 2.

Profile depth (in)	1 SWWW-CVF	1 CVF-SWWW	2 SWWW-CHF	3 SB	4 SWSW	5 DNS
0-6	128	1,778	330	79	366	676
6-12	389	1,512	681	238	789	715
12-18	679	1,323	448	243	641	145
18-24	401	168	995	137	842	8
24-36	0	241	188	0	9	0
36-48	0	7	1	0	1	0
mean: 0-24	399	1,195	614	174	660	386

References

Perrett, J. 2004. Using prior information on the intraclass correlation coefficient to analyze data from unreplicated and under-replicated experiments”. Ph.D. Thesis, Kansas State University, Manhattan.