Long-Term Continuous Annual Cropping in the Pacific Northwest (PNW): Tillage and Fertilizer Effects on Grain Yield and Profitability of Winter Wheat, Spring Wheat, and Spring Barley

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Introduction

Much of eastern Oregon receives <17 inches of annual precipitation (70% occurs during winter months) and winter wheat (*Triticum aestivum* L.) tillage-based summer fallow is the predominant cropping pattern. Tillage fallow is practiced to control weeds, accumulate nutrients, and slow the evaporative loss of soil moisture. Soil tillage aerates the soil and accelerates biological oxidation and loss of soil organic matter. Loss of SOM can be reduced by conservation tillage and annual cropping. With the introduction of no-tillage (NT) practices, there is a renewed interest in annual cropping of winter wheat. In NT systems residues remain on the surface and protect soil from erosion at all times. The soil macropores that remain intact in NT facilitate rapid water infiltration. Surface residues form mulch that aids water infiltration and reduces evaporation. Increased water infiltration and reduced evaporation increase the potential water storage of the soil and may increase crop productivity under dryland conditions.

Information on crop productivity and profitability of continuous winter wheat (WW), spring wheat (SW), and spring barley (SB) using CT and NT cropping systems in the PNW is limited. The objective of our experiment was to determine the effects of annual mono-cropping of WW, SW, SB on grain yield and profitability under CT and NT cropping systems.

Materials and Methods

The experiment was conducted at the Columbia Basin Agricultural Research Center (CBARC), Oregon State University (OSU), near Pendleton, Oregon. The soil is a coarse, silty, mixed, mesic Typic Haploxeroll (Walla Walla silt loam); the soil is 4 ft to caliche and about 8 ft to bed-rock. Average annual precipi-tation is about 400 mm. The WW, SW and SB plots were initiated in 1931, 1977, and 1982, respectively. Since then plots have gone through several changes. In 1993, all crop sections were divided into two strips each with four plots. Each of the four plots in one section are fertilized and the other four are not. The fertilized plots of WW, SW, and SB receive 90, 80, and 80 lb N/acre, respectively. NT companion plots WW, SW, and SB were initiated in 1997 and fertilized plots receive 100, 90, and 90 lb N/acre, respectively. All fertilized plots receive 12 lb P/acre and 18 lb S/acre, annually. Target seeding rates for CT and NT plots were 22 and 25 seeds/ft^2, respectively for WW, 26 and 29 seeds/ft^2, respectively, for SW and 23 and 26 seeds/ft^2, respectively for SB. A JD8300® double disk drill with a 6.7-inch row spacing was used to seed CT plots and a JD1560 with a 7.4-inch row spacing or a ConservaPak® drill with a 30-cm row spacing was used to seed the NT plots. Varieties of WW, SW, and SB seeded in this experiment were "Stephens", "Alpowa" or "Zak", and "Baronesse", respectively. Weeds are controlled by herbicides. Grain was harvested by a plot combine and weighed. Yield components were determined from a 1-m quadrat in each plot. PROC MIXED and REPEATED MEASURES procedures (SAS) were used to analyze data. A partial economic analysis was performed. Fixed costs, crop insurance costs, and government programs benefits were excluded. Variable costs were assigned to residue management and tillage for seedbed establishment, seeding, fertilizing, weed control, and interest. Variable costs were based on the OSU Enterprise Budget for Winter Wheat. Fertilizer and pesticide costs were based on local dealers. Prices for soft white wheat were the Portland, OR November average price for the harvest year crop.

Results and Discussion: Agronomy

Precipitation

Pendleton, the 73 year average crop year precipitation is about 16 inches. Crop-year precipitation was greater than the 73 yr average in 1999 and 2000 but was less in the last 4 years of the study. Grain yields decreased with the decreasing precipitation in the last four years of the study.

Grain Yield

The six year average grain yields of all crops are shown in Figure 1. Yield components are shown in Table 1. In unfertilized plots, grain yields of all the crops using CT were higher than grain yields of crops using NT. The difference was greater in spring crops than in WW with the greatest difference in SB yields. Higher grain yields in unfertilized CTWW were due to higher HI and heavier kernels in CTWW than in NTWW. In unfertilized SW plots, higher grain yield under CT was probably attributed to higher kernel weights in CTSW than NTSW. Unfertilized CTSB produced higher grain yields than NTSB through high numbers of heads/ft^2. Reduced NT grain yields in unfertilized plots indicate that there were substantial problems associated with NT cropping systems. Low yields using NT could be attributed to N deficiency due N immobilization, slow growth due to cold wet soils, increased disease and weed pressure, and residue toxicity.

Applying N, P, and S increased grain yield of all crops under both CT and NT cropping systems. When fertilized, there were no significant differences in grain yields between CTWW and NTWW. Although there were significantly more heads/ft^2 in NTWW than in CTWW, the reduction in kernel weight and HI under NT probably led to comparable grain yields between CTWW and NTWW. In spring crops, fertilizer application did not equalize the grain yield between CT and NT systems. High grain yields in CT plots were attributed to significantly more heads/ft^2 in fertilized plots of both SW and SB than in NT plots.

Overall, SB produced the highest grain yields under unfertilized CT conditions and WW produced the highest grain yields under unfertilized NT systems. In fertilized plots, SB produced the highest grain yields under both CT and NT conditions followed by WW and then SW. SB produced high grain yields through more heads/ft^2 and earliness to maturity. SB grew more rapidly than SW matured at about the same time as WW. In contrast, SW matured last and its grain filling period coincided with drought and high temperature stresses.

Table 1. Tillage and fertilizer effects on grain yield and yield components of continuous annual winter wheat, spring wheat, and spring barley at CBARC, Pendleton, OR (1998-2003)

Crop	Tillage	Fert	Plants/ft²† (02-03)	Plants/ft² (% target)	Heads/ft² (02-03)	Heads/plant	Harvest Index (00-03)	1000 kernel wt (oz)	Grain yield (lbs/a)
WW	CT	0	13	59	20a	1.6	0.47a	1.65a	2286a
WW	NT	0	22	88	19a	0.9	0.39b	1.39b	1946b
SW	CT	0	20a	77	24b	1.2	0.46a	1.30a	1964a
SW	NT	0	21a	72	26a	1.3	0.44a	1.17b	1464b
SB	CT	0	19b	82	41a	2.2	0.51a	1.40a	3000a
SB	NT	0	21a	80	29b	1.4	0.43b	1.29b	1518b
WW	CT	F	11	50	29b	2.6	0.41a	1.53a	3152a
WW	NT	F	19	76	32a	1.7	0.39a	1.33b	3196a
SW	CT	F	21b	81	39a	1.8	0.39a	1.08a	2938a
SW	NT	F	25a	86	29b	1.1	0.39a	1.07a	2313b
SB	CT	F	19b	83	60a	3.1	0.42b	1.23b	3946a
SB	NT	F	27a	104	48b	1.8	0.48a	1.30a	3348b

† se applies to spring wheat and spring barley
Means with the same letter are not significantly different at the 0.05 probability level

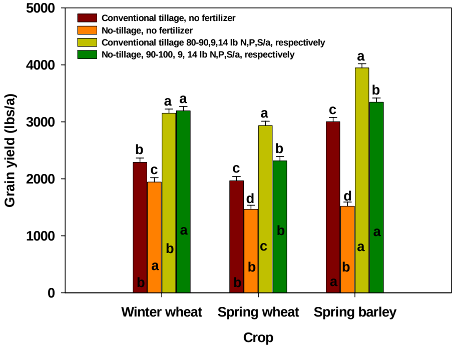

Figure 1. Tillage and nitrogen effects on grain yield of continuous winter wheat, spring wheat, and spring barley at CBARC, Pendleton, Oregon. Yields are six year means (1998-2003). Means with the same letters are not significantly different from each other. Letters at the top of bars compare yields within each crop and letters within bars compare yields between crops with the same tillage and fertilizer rates.

Results and Discussion – Economic Analysis

The average cost of the residue management in NT plots was $32.93 ha^{-1} compared to average tillage costs for the CT plots of 70.06 ha^{-1}. Fertilization costs were similar for each system. Planting costs, including the seed and seeding, were about $12 ha^{-1} greater for the NT than the CT plots because the seeding rate was increased and the cost of seeding with a no-till drill was greater than with a conventional drill. Herbicide costs tended to increase each year, regardless of tillage. Herbicide costs were the single largest input for both CT and NT plots; costs varied from $53.87 to $167.15 ha^{-1} for the CT plots and from $129.13 to $191.45 ha^{-1} for the NT plots. Total average annual variable input costs were $339.62 ha^{-1} and 376.35 ha^{-1} for the CT and NT plots, respectively.

Crop yields, crop values, variable input costs, and partial net returns are shown in Table 2. Crop values varied in response to changes in the crop yields and crop prices; the mean crop value for the CT and NT crops were essentially equal. The variable input costs were greater for the NT than the CT plots, primarily due to the greater herbicide expense in the NT plots. The partial net returns were extremely variable, due to the interacting effects of crop yields, crop prices, and variable input costs. The partial net returns from the CT plots ranged from $337.18 to -$33.10 ha^{-1} with a mean partial net return of $108.41 ha^{-1}. The partial net returns from the NT plots ranged from $154.47 ha^{-1} to -$26.13 ha^{-1}; the average annual partial net return was $74.60 ha^{-1}.

Table 2. Crop yield, crop value, variable costs, and partial returns from fertilized CT and NT WW, SW, and SB at CBARC, 1998-2003.

	Crop Yield		Crop Value		Variable Input Costs		Partial Net Return	
	CT	NT	CT	NT	CT	NT	CT	NT
Crop	Lbs/acre		---------------------- $/acre ----------------------					
Winter Wheat	3152	3196	181.45	182.63	137.55	152.43	43.91	30.21
Spring Wheat	2938	2313	167.46	132.82	118.72	128.01	48.75	3.80
Spring Barley	3946	3348	193.47	162.87	116.27	125.08	77.20	37.79

Summary and Conclusions

- •Unfertilized CT winter wheat performed better than unfertilized NT winter wheat, indicating problems in NT systems.
- •Winter wheat produced similar yields using both can be grown CT and NT cropping systems when fertilized. Fertilized spring crops consistently produced lower yields under NT, indicating problems in NT cropping systems. Breeding and agronomic work is required to bring out the full potential of continuous NT wheat and barley.
- •Continuous CT crops had lower variable costs of production, especially herbicides, and greater economic returns than NT crops.