Agronomic and Economic Comparison of Annual-Cropped Conventional Tillage and No-Tillage. I. Winter Wheat

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Introduction

Much of eastern Oregon receives <425 mm of annual precipitation (70% occurs between September and March) 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 under 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 winter wheat 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 1.2 m to caliche and about 2.4 m to bed-rock. Average annual precipitation is about 400 mm. The CT plots have been in continuous winter wheat since 1931 with a range of N fertilizer treatments during the period 1931-1992. Beginning in 1977 to date, CT plots received 100, 10, 16 kg N, P, S ha^{-1}, respectively. A no fertilizer treatment was imposed in 1993. NT companion plots receiving 112, 10, 16 kg N, P, S ha^{-1}, respectively, with a control were established in 1997. Data obtained from 1998 to 2003 is presented. Seeding was done in October at 237 and 269 seeds m^{-2} for the CT and NT, respectively. A double disk drill was used to seed CT plots and a hoe drill was used to seed the NT plots. Weeds were controlled by glyphosate, metribuzin, glyphosphate + 2,4-D, bromoxynil, imazamox, sulfosulfuron, diclofop methyl, and triallate. 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

Winter wheat grain yields were influenced by winter and spring precipitation during the six years of this study. Crop year precipitation (1 Sep to 31 Aug) was greatest in 2000 and least in 2002 while winter precipitation was greatest in 1999 and least in 2002. Spring precipitation was highest in 2000 and lowest in 1999.

Grain Yield

Grain yields of unfertilized CT winter wheat were weakly correlated with spring precipitation while unfertilized NT grain yields were influenced by winter precipitation (Table 1). Preliminary data indicate that NT plots stored more winter precipitation than CT plots and were, therefore not so dependent on spring precipitation as CT plots. Grain yield of unfertilized CT winter wheat was significantly higher than grain yield of NT winter wheat in four of six years (Fig. 1). In similar studies, low NT grain yields were 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 CT grain yields in four of six years and NT grain yields in five of six years (Fig. 1). Grain yields of fertilized CT winter wheat were significantly influenced by spring precipitation (Table 1, Fig. 1). NT grain yields were influenced equally by both winter and spring precipitation (Table 1, Fig.1). There was no advantage of fertilization in 1999 and 2003 because of soil moisture shortage during the spring (Fig 1). High grain yield in fertilized plots were obtained in 1998, 2000, and 2001. In all these years, both winter and spring precipitation were high.

Grain yields of fertilized CT and NT winter wheat were not significantly different in four of six years (Fig. 1) suggesting that fertilization overcame the negative effects of NT conditions, particularly N deficiency, in those years.

Overall, CT grain yields were higher than NT grain yields when grown without fertilizer. Heads m^{-2}, harvest index (HI), and kernel weight were lower in unfertilized NT winter wheat than in unfertilized CT winter wheat (data not shown). CT and NT grain yields were not significantly different when grown with fertilizer. Higher numbers of heads m^{-2} in NT wheat were counteracted by a high HI and kernel weight in CT winter wheat (data not shown).

Table 1. Correlations between grain yield of unfertilized and fertilized continuous winter wheat grown under conventional tillage and no-tillage systems

	Conventional Tillage Yield		No-tillage Yield	
Fertilizer	0	100,10,16 kg N,P,S ha^{-1}	0	112,10,16 kg N,P,S ha^{-1}
Crop year ppt	†0.31*	0.32*	0.37**	0.79**
Winter ppt	0.16	-0.09	0.59**	0.55**
Spring ppt	0.32*	0.76**	-0.24	0.62**

†*,** significant at 0.05 and 0.01 probability levels, respectively

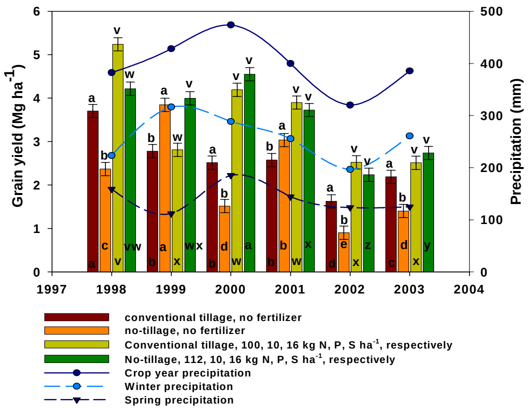

Fig. 1. Precipitation, tillage, and fertilization effects on the grain yield of continuous winter wheat, CBARC, Pendleton, OR, 1998-2003. Means with same letters are not significantly different from each other at the 0.05 probability level. Letters a,b at the top of bars compare unfertilized plots and v,w compare fertilized plots within each year. Letters within bars compare the same fertilizer treatment between years (a,b,c,d,e for unfertilized plots and v,w,x,y,z for fertilized plots)

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 winter wheat at CBARC, 1997-2003.

Year	Crop Yield		Crop Value		Variable costs		Partial net return	
	CT	NT	CT	NT	CT	NT	CT	NT
	Mg ha^{-1}		------------------------------ Mg ha^{-1} ------------------------------					
1998	5.25	4.22	606.90	488.41	269.72	334.56	337.18	153.85
1999	2.81	4.00	318.65	453.60	318.33	396.93	0.32	56.67
2000	4.19	4.55	452.64	491.49	336.22	382.55	116.42	108.94
2001	3.90	3.74	536.76	514.05	314.60	359.58	222.16	154.47
2002	2.53	2.24	415.98	368.30	408.51	394.43	7.47	-26.13
2003	2.52	2.75	357.21	389.87	390.31	390.09	-33.10	-0.22
Mean	3.53	3.58	448.02	450.95	339.62	376.36	108.41	74.60

Summary and Conclusions

- Winter wheat can be grown successfully in both CT and NT cropping systems in the PNW in areas receiving annual precipitation of 400 mm.
- Unfertilized CT winter wheat performed better than unfertilized NT winter wheat, indicating problems in NT systems.
- Although applying N, P, and S fertilizer increased NT grain yields to the level of CT grain yields, breeding and agronomic work in required to bring out the full potential of continuous NT winter wheat.
- Continuous CT winter wheat had lower variable costs of production, especially herbicides, and greater economic returns than NT winter wheat.