Tillage Effects on Water Use and Grain Yield of Winter Wheat and Green Pea in Rotation

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Introduction

A 7-year study, to evaluate the effect of different tillage methods and timing of tillage operations on water storage, water use, and grain yield of winter wheat (*Triticum aestivum* L.) and green pea (*Pisum sativum* L.) in rotation, was conducted at the Columbia Basin Agricultural Research Center (CBARC) near Pendleton, Oregon, USA. About 70% of precipitation (400 mm total) falls from September to February and so crops, that start rapid growth in March, mature under increasing drought and heat stresses. Under these conditions, cropping practices that increase water use efficiency (WUE) are required to optimize yield.

Methods

Data (1977-1985) discussed in this paper were obtained from the wheat-pea rotation long-term experiment at CBARC, Pendleton, Oregon (45.7°N, 118.6°W, elevation 438 m) that was established in 1963 and still on-going. Tillage treatments included maximum tillage (MT), fall plow (FP), spring plow (SP) [FP during the wheat phase (SP(FP)], and minimum tillage (MinT). Soil water content measurements, to a depth of 2.5 m, were obtained using neutron attenuation after harvest and in spring. Water storage (WS) is the difference between soil water in the 2.5-m soil profile measured after harvest and in spring. Storage efficiency (SE) is water stored from harvest to the first spring soil water reading expressed as a percentage of precipitation for the same period. Water extraction (WE) is the difference between water content in the soil profile measured in spring and the water content measured after harvest. Growing season evapotranspiration (GSET) was the sum of growing season precipitation (GSP) and WE. Drainage, runoff and erosion were assumed to be negligible. Water use efficiency (WUE) was determined using the following equation:

$$WUE = \frac{GY}{(GSET)}$$

where GY is grain yield (Mg ha^{-1}) and GSET is growing season evapotranspiration.

Grain yield Wheat was harvested with plot combines. Harvested area was 2.5 m x 36 m. Grain was cleaned using a screen air cleaner, weighed, and reported on a dry weight basis. Green pea, at a tendrometer reading of about 98, was swathed using a locally designed draper swather with a 3.7-m platform. Vines from each plot were hauled to a central stationary thresher where green pea were removed from vines, cleaned of debris, weighed, and reported on a fresh weight basis.

Data analysis The experimental design was a split plot in a randomized complete block arrangement with four replications. Crops (winter wheat or green pea) were assigned to main plots and tillage treatments were assigned to sub-plots. Each replication contains eight plots (four tillage treatments for each of the two crops in rotation). Duplicate treatments, offset by one year, ensure yearly data collection for both wheat and peas. Since experiments were conducted for each plot from 1977 to 1982, and 1985, the data from each plot are correlated over time. Data were analyzed by PROC MIXED procedures with repeated measures for year in conjunction with Auto-Regressive time series modeling procedures. Results obtained in 1983 and 1984 were omitted because of missing soil water data.

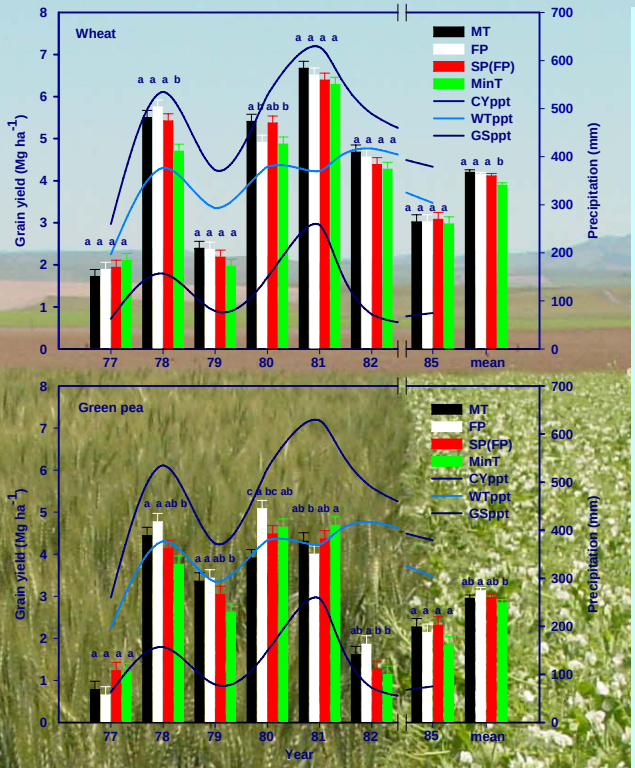

Fig. 1.Maximum tillage (MT), fall plow (FP), spring plow (SP) (FP for wheat), and minimum tillage (MinT) effect on grain yield of winter wheat and green pea in rotation at CBARC, Pendleton, OR from 1977 to 1982 and 1985. The graphs also show crop-year precipitation (CYppt) (1 Sept-31 Aug), winter precipitation (WTppt) (1 Sept-28 Feb), and growing season precipitation (GSppt) (1 March-31 Aug). Means (within each year) with the same letter are not significantly different at the 0.05 probability level.

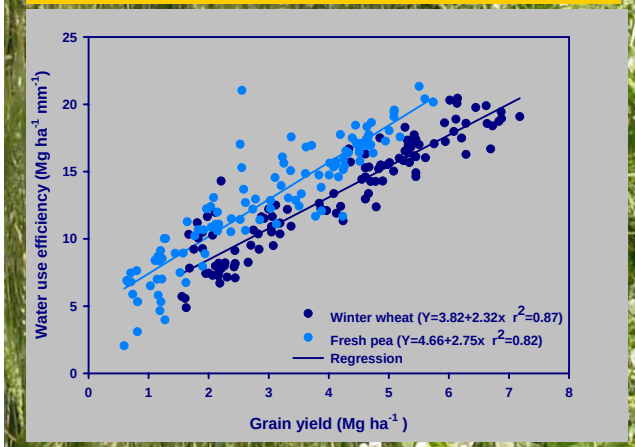

Fig. 2. Grain yield and water use efficiency of winter wheat and green pea in rotation at CBARC, Pendleton, OR. Data shown are 7-yr means (1977 to 1982 and 1985).

Results and Discussion

Wheat and pea yields were not significantly different between MT, FP, and SP(FP) treatments. MinT produced the lowest yields in both wheat and green pea phases and this was significantly so for wheat (Fig. 1).

During the wheat phase, MT, FP, and SP(FP) stored more water than MinT. MinT stored the least water due to low surface residues; pea residues were removed at harvest. Wheat yield under MinT was reduced probably due to a combination of low water storage and heavy downy brome (*Bromus tectotum* L.) infestation. During the pea phase, MinT stored the most water, but this proved advantageous only in a very dry year when crop-year precipitation dropped to 260 mm. During the pea phase, most water was stored under SP and MinT treatments that had standing wheat stubble during the winter months. In years with near normal precipitation, the additional water in SP and MinT treatments was of little advantage as yields were hampered by weeds and other problems associated with high wheat residue conditions.

There were no significant tillage effects and tillage and year interactions on the amount of water extracted by both wheat and peas. In general, there was more water extracted in years where crop-year precipitation was high.

There were no significant tillage effects and tillage and year interactions on WUE during the wheat phase. WUE was highly correlated with wheat grain yield under all tillage treatments ($r=0.87$, $P<0.01$) (Fig. 2). The correlation was highest under MinT. There were significant tillage and year interactions on WUE during the pea phase. Tillage had no significant effect on WUE in either 1977, the driest year of the study period or in 1978, a year with twice as much precipitation as 1977. In other years with high precipitation, tillage effects were not consistent. WUE was highly correlated with green pea yield ($r=0.82$, $P<0.01$)(Fig. 2). The correlation was highest under MinT during the green pea phase.

Conclusions

The choice of tillage practice for wheat-pea rotation in eastern Oregon should, therefore, be based on the interaction of factors that increase water use efficiency and yield. Leaving wheat stubble over-winter, as in SP and MinT treatments during the pea phase, increased soil water storage. However, storing the most water without adequate weed control did not guarantee high yields as was the case with MinT during the pea phase. Weed control under MinT should make this tillage practice very competitive. Under limited water conditions, as in eastern Oregon, any improvement in agronomic practices that increase yield will ultimately increase WUE.

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