Water Use and Water Productivity of Dryland Winter Wheat in the High Plains Ecoregion of Wyoming

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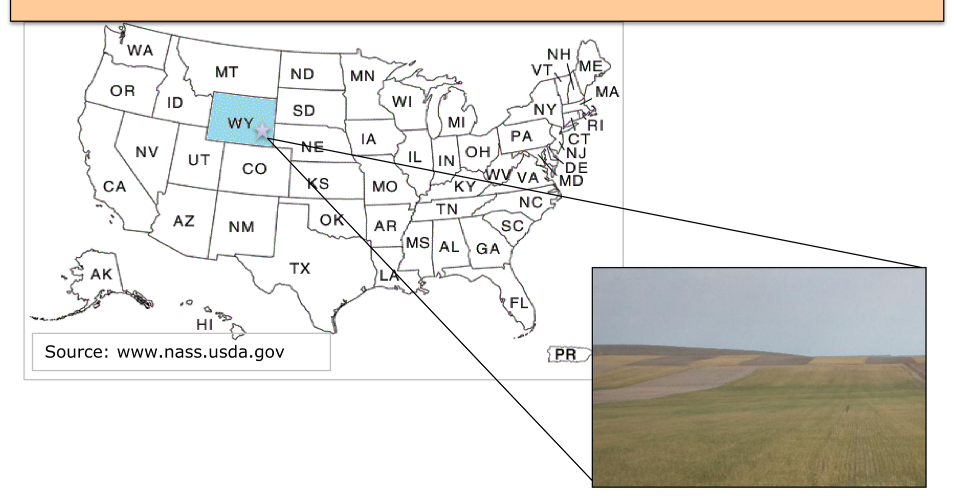
Introduction

- Water is the major limiting factor for dry land crop production in the semiarid areas of the U.S. Great Plains (Smika, 1970).
- The conventional dryland winter wheat production system in Wyoming includes 14 months of fallow between two wheat crop seasons. The system seems to be inefficient as soil water storage efficiency during fallow is frequently less than 25% with conventional tillage (McGee et al., 1997).
- The objectives of this study were to determine the water use and water productivity of conventional, no till and organic production practices of dry land winter wheat in Wyoming.

Materials and Methods

Location

Figure 1 – Map of US highlighting Wyoming. A typical dryland winter wheat field in the region is shown in the picture.



- The experiment was conducted at University of Wyoming Sustainable Agricultural Research and Extension Center (SAREC), near Lingle, Wyoming (Fig. 1).
- SAREC is located at a latitude of 42.5° N, longitude of 104.13° W and at an elevation of 1249 m above sea level.
- The soil of the experimental site is characterized as silt loam, deep and well drained (coarse-silty, mixed, superactive, calcareous, mesic Ustic Torriorthents) (www.soilseries.sc.egov.usda.gov).
- The region has an average annual rainfall of 334 mm and average annual mean air temperature of 8°C (www.wrcc.dri.edu).
- The growing season in Wyoming is short with long winters, having an average frost free period of 125 days (www.wrds.uwyo.edu).

The Experiment

- A dry land winter wheat experiment, consisting of three cropping system was initiated in 2009.
- The wheat variety goodstreak was planted in conventional, no-till and organic cropping systems utilizing a completely randomized design with three replications. For the results presented in this study, the crop was planted in September 2011 and harvested in July 2012.
- Information about crop growth, soil, and environmental conditions was obtained:
  - ✓ Soil moisture was monitored utilizing a neutron probe. Weekly readings were conducted at 20 cm intervals to a depth of 140 cm. Soil samples were taken to determine gravimetric soil moisture for neutron probe calibration.
  - ✓ Environmental conditions, including rainfall, air temperature, relative humidity, solar radiation, and soil temperature were recorded hourly by an automated weather station located in the experimental site.
  - ✓ Yields were obtained at 12% moisture by manually harvesting 1m length of rows taken randomly in each plot.

The Statistical Analysis

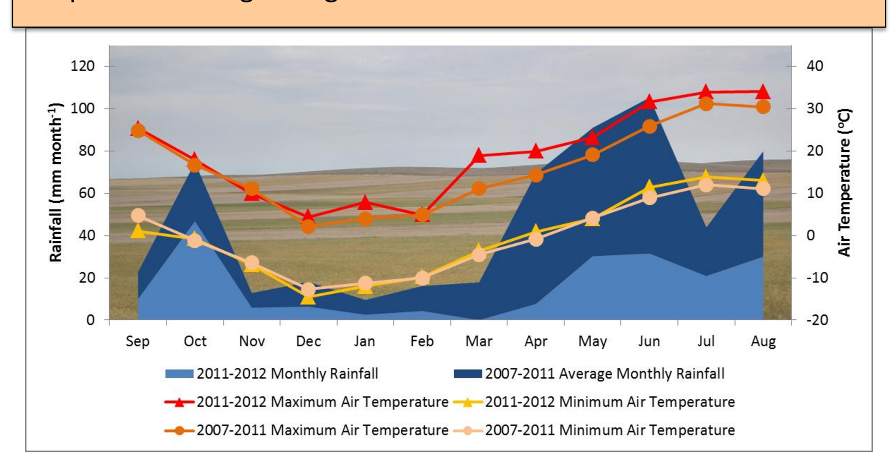
- The PROC GLM of SAS was used to perform Analysis of Variance to assess the effect of cropping systems on yield, water use and water productivity. Multiple comparisons of mean values were performed by the least-significant difference method (LSD) for a probability level of $P < 0.05$.

Results

Weather Conditions

- The 2011-2012 growing season was extremely dry. While the average rainfall of the previous five years was 314 mm, only 159 mm were recorded during the 2011-2012 growing season (Fig. 2).
- Due to dry conditions, accumulation of snow was scarce. As a consequence, wheat seedlings were, during most of the winter, directly exposed to very low air temperatures.

Figure 2 – Weather conditions at the UW Sustainable Agricultural Research and Extension Center (SAREC) during the 2011-2012 and the previous four growing seasons.



- The 2011-2012 growing season was warmer than previous seasons. Air temperature as high as 33°C (4-growing season average = 29°C) and as low as -10°C were observed (Fig. 2).
- Regardless the cropping system, limited rainfall restricted growth and yield of wheat.

Soil Moisture

- At planting, in all three cropping system fields, soil moisture was at 80 percent of field capacity in the first 30 cm soil layer (Fig. 3).
- Initial soil moisture conditions were sufficient for acceptable crop establishment.
- The crop extracted water in the whole soil profile, evidencing that the rooting system explored deep layers of soil in all cropping systems. However, changes in soil moisture were different between cropping systems (Fig. 3).

Figure 3 – Variation on soil moisture content in the soil profile at the beginning and end of crop season.

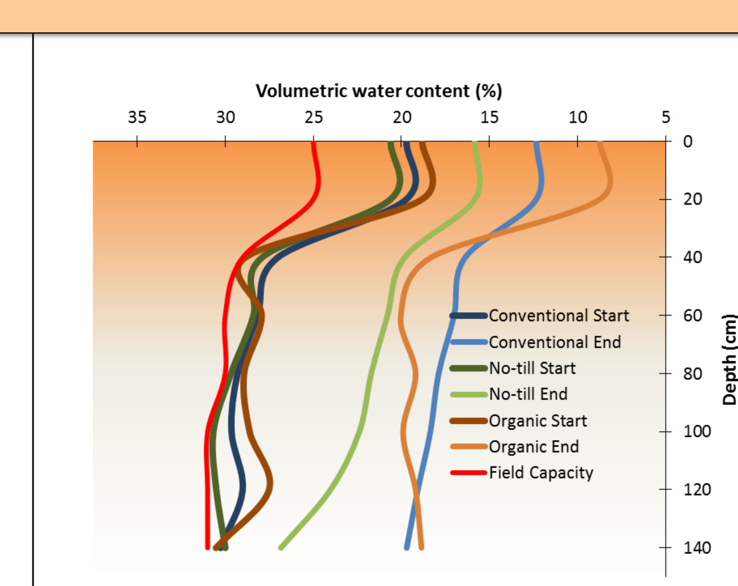
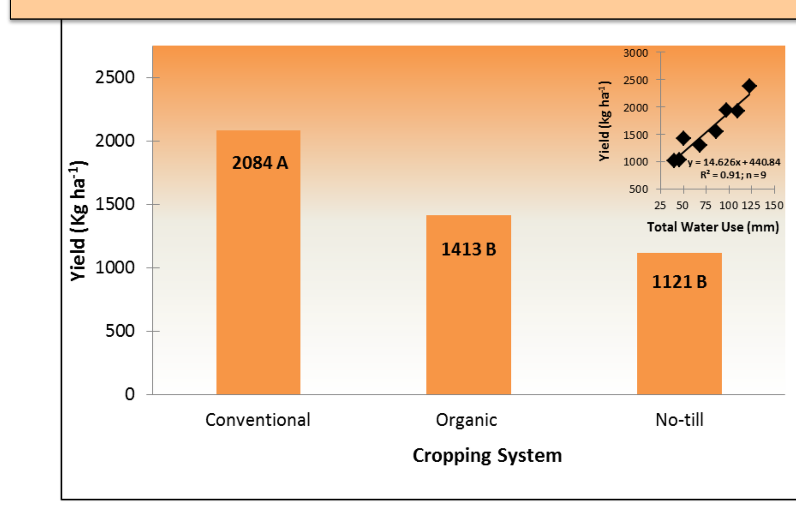


Figure 4 – Average dryland winter wheat yield under different cropping systems (yield values with the same letter are not significantly different).



- The total water use was estimated from effective rainfall and changes in soil moisture content. Because of dryland conditions with little rainfall, deep percolation, run-off, and drainage losses were not considered in the water balance calculations.
- Significant differences ($P < 0.05$) on water use were found between conventional and no-till winter wheat. Water use of wheat in the organic system was not different to conventional and no-till systems (Fig. 5).

Yield and Water Use

- There were significant differences ($P < 0.05$) in yield of winter wheat grown under conventional, organic, and no-till cropping systems (Fig. 4).
- Yield from no-till and organic practices was lower than expected. Less inputs in the organic practice and few years of no-till may be the reasons.
- The variation in yield may be because of differences in water use between the three cropping systems. There were 24 mm and 59 mm more water use in conventional system compared to organic and no-till practices, respectively.
- Winter wheat yield increased linearly with increasing water use by the crop (Fig. 4; embedded).
- For every unit increase in water use, there were 14.63 units increase in winter wheat yield.

Figure 5 – Total water use under different cropping systems (water use values with the same letter are not significantly different).

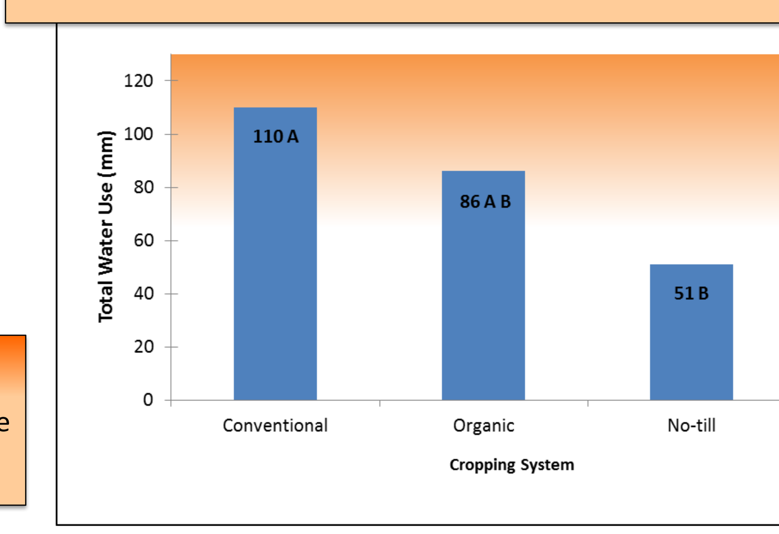
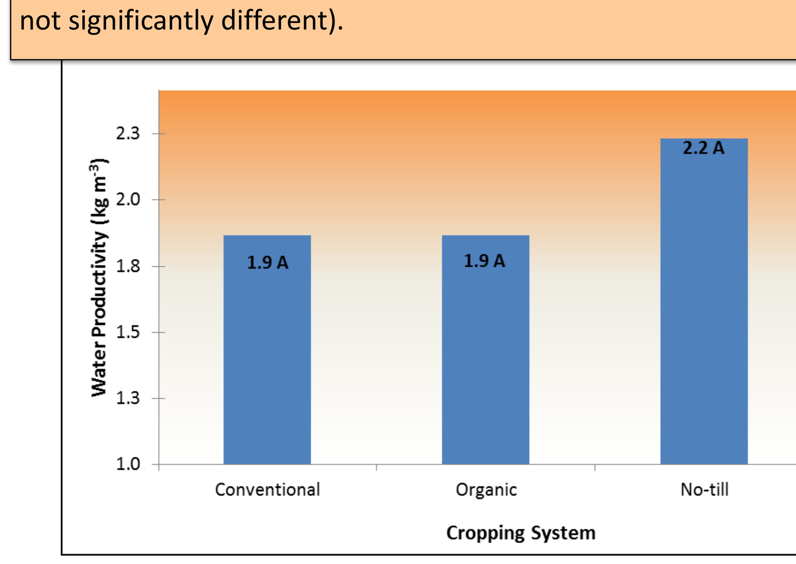


Figure 6 – Water productivity of winter wheat under different cropping systems (water productivity values with the same letter are not significantly different).



Water Productivity

- Water productivity was calculated as the ratio of yield to total water use.
- No differences in water productivity were found between cropping systems (Fig. 6).
- Dryland winter wheat produced under the no-till system showed slightly higher water productivity. This may be an evidence of less water losses due to soil evaporation.

Conclusions

- All three cropping systems showed significant differences in yield and water use. However, dryland winter wheat grown in the conventional system produced higher yield than in the organic and no-till systems.
- There was no effect of cropping system on water productivity of dryland winter wheat. No-till and organic production systems seem to be as efficient as the conventional practice in the use of soil moisture for crop needs.
- Further steps include to continue studying the impact of cropping systems on the long term and to confirm the results here presented with more years of experiments. Crop models coupled to decision support systems will also be used.

Acknowledgements

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