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Understanding Water Needs of Diverse, Multi-year Crop Rotations

BY JEFF STROCK AND BRENT DALZELL

Crop rotation diversification is the most powerful tool that farmers have to reduce economic risk, disrupt pest cycles, increase soil resilience, and improve water quality (Teasdale et al., 2007). As investigators with the Sustainable Corn Project, we are now conducting studies to determine if diverse, multi-year rotations also can help crops thrive as precipitation patterns change in the Corn Belt.

In the upper Midwestern United States, annual precipitation is projected to increase mostly during the non-growing season while summer precipitation patterns are expected to become less predictable. Too much water early in the growing season can lead to delayed planting, crop loss, and environmental damage while too little water in the summer can lead to reduced yields or total crop loss.

> Besides yield, water use efficiency is an important agronomic factor.

In our research we are quantifying soil water budgets and crop water use — the relationship between input and output of water within the soil and through a plant. We're also studying the environmental response of diverse, multi-year organic and conventionally managed crop rotations in order to identify which crop rotations and rotation lengths are most resilient under various climate conditions, including changing precipitation patterns. This is being accomplished through a combination of plot-scale studies and modeling.

Improved understanding of water use by more diverse cropping systems can help farmers determine which rotations are best suited for their particular location and precipitation pattern. Understanding the mechanisms for increasing soil water storage and plant water use efficiency will help farmers be economically competitive while also minimizing their environmental impact.

Water use efficiency is a quantitative measurement of how much biomass or yield is produced over a growing season, normalized with the amount of water used by a plant in the process. Besides yield, water use efficiency is an important agronomic factor, especially in agricultural systems because changing precipitation patterns, frequency, intensity and distribution will alter soil water availability for crop production.

Sustainable Corn Project Preliminary Results

Table 1 (below) shows the water use efficiency for selected crops and rotations during August to October 2013. During this partial season, corn from the 2-year conventional rotation (corn following soybean) was 1.3 to 1.5 times more efficient with respect to water use efficiency compared to corn from either of the 4-year rotations (corn-soybean-oat/alfalfa-alfalfa). There was no difference among soybean water use efficiency for any of the rotations.

The average changes in soil water storage for the represented cropping systems were not significantly different during this period of time. The data do indicate that the 2-year conventional rotation used less water than the perennial or extended rotations but the difference was not significant (Figure 1 next page).

Grain yield is shown in Figure 2 (next page). Grain yield and biomass yield (alfalfa) were similar between the organic and conventional 4-year rotations. Soybean yield for the 2-year rotation was similar to both 4-year rotations. In contrast, corn grain yield for the 2-year rotation was significantly greater than for both 4-year rotations.

Next Steps

Sustainable Corn Project researchers are only in the early stages of data collection. As more data are collected and analyzed, the information gained from this project will assist producers in making management decisions that will lead to increased water use efficiency, nutrient use efficiency and long-term conservation. This will help to make farming systems more productive and profitable while also minimizing their environmental impact.

TABLE 1 | WATER USE EFFICIENCY FOR SELECTED CROPS AND ROTATIONS DURING AUGUST TO OCTOBER, 2013

Component (in)	Organic 4-yr Rotation		Conventional 4-yr Rotation		Conventional 2-yr Rotation	
	CORN	SOYBEAN	CORN	SOYBEAN	CORN	SOYBEAN
Water Use Efficiency (WUE, lb/ac-in) (Higher numbers represent greater efficiency than lower numbers)	1352	345	1149	397	1718	380

FIGURE 1 | SOIL WATER STORAGE

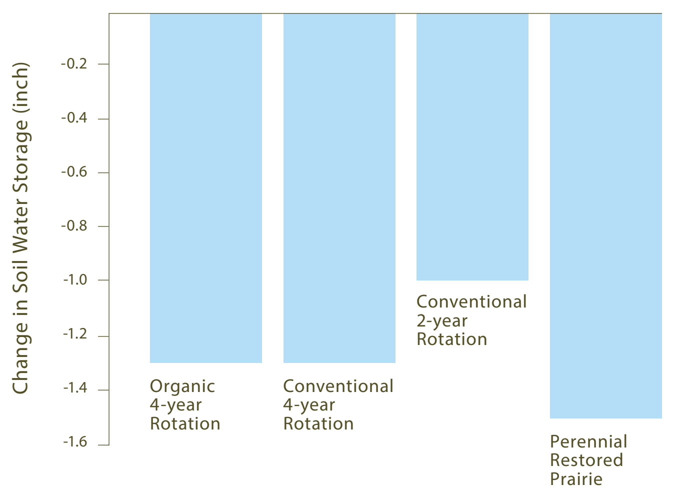
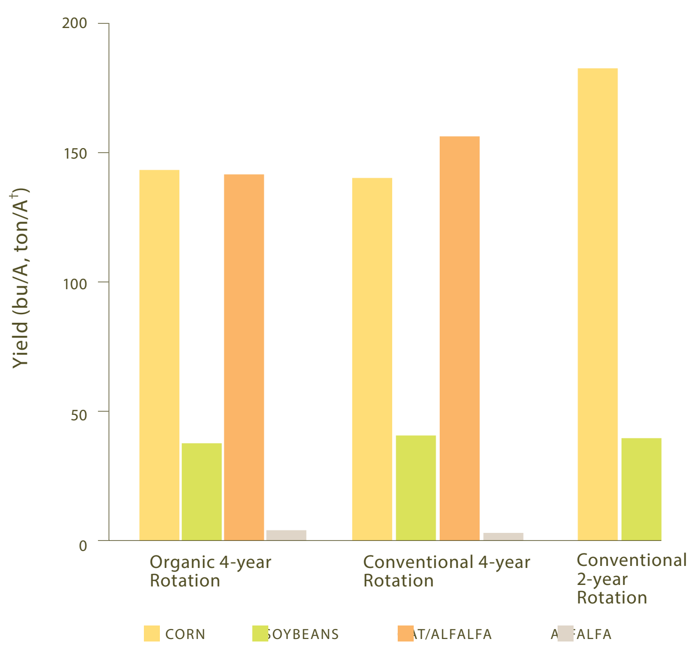


FIGURE 2 | GRAIN YIELD



Jeff Strock, Ph.D., is a professor and soil scientist in the Department of Soil, Water and Climate & Southwest Research and Outreach Center at the University of Minnesota and a principal investigator with the Sustainable Corn Project.

Brent Dalzell is a research associate and biogeochemist on the Sustainable Corn Project at the University of Minnesota.

WATER

Climate patterns in the central US are expected to become increasingly variable with changes in precipitation intensity and seasonality and changes in available soil water for crop production. Prevailing weather conditions, available water in the soil, crop species, and development stage influence crop water use. Water is an important factor in crop production. Approximate seasonal water requirements for corn, soybean and small grains are similar and range between 20–32, 18-28 and 18–26 inches, respectively, for optimum yield depending on variety, crop and water management. Seasonal water requirements for alfalfa are considerably greater and range between 32 and 63 in. Evapotranspiration (ET) plays a key role in the water cycle, affecting the water balance from local up to regional scales and causing feedback between soil, plants and the atmosphere. Because ET can comprise approximately 75-85% of the annual water budget in the upper Midwest, accurate representation of it in crop water budgets is crucial for quantifying the effect of changes in land use and management on water balances (e.g. diverse crop rotations, perennials, cover crops) (Hatfield et al., 2001).

Recently, it has been demonstrated that landscape-scale changes in cropping patterns can influence water, yield and nonpoint source pollution (Schilling et al., 2008). Furthermore, watershed-scale studies in south-central Minnesota have shown that water-yield differences, especially differences in the timing of ET, between row crops (corn-soybean) and perennial crops (prairie grass and switchgrass) may explain over 70% of current sediment export from some watersheds (Dalzell and Mulla, in prep).

< This soil moisture sensor, installed in organic and conventional rotations at the University of Minnesota, monitors plant-available water in the soil profile.