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Water Use and Productivity of Corn and Grain Sorghum in Long-Term Crop Sequences

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Abstract

Dryland corn and grain sorghum showed similar water productivity of grain and above-ground biomass, relative to respective growing periods, at the apparent yield frontier. The yield frontier indicates the maximum productivity for a given amount of water use. This similarity in productive response to water supply provides a foundation for improved precipitation use. Yield gaps relative to the yield frontier appear substantial. Water supply during the grain filling period was the primary driver of feed grain crop productivity, and was affected more by available soil water at pollen shed than by precipitation during grain-fill or available water at maturity. Grain sorghum and corn differed in responses to annual conditions, offering potential for risk management.

Keywords

corn, grain sorghum, water use, dryland, cropping system

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Summary

Dryland corn and grain sorghum showed similar water productivity of grain and above-ground biomass, relative to respective growing periods, at the apparent yield frontier. The yield frontier indicates the maximum productivity for a given amount of water use. This similarity in productive response to water supply provides a foundation for improved precipitation use. Yield gaps relative to the yield frontier appear substantial. Water supply during the grain filling period was the primary driver of feed grain crop productivity, and was affected more by available soil water at pollen shed than by precipitation during grain-fill or available water at maturity. Grain sorghum and corn differed in responses to annual conditions, offering potential for risk management.

Introduction

Crop water productivity (ratio of above-ground biomass or grain to growing season water use) is an important component of precipitation use. Warm-season grass crops maintain water productivity with large intrinsic transpiration efficiency and enhanced tolerance of warmer temperatures. The timing and quantity of water supply frequently constrains grain productivity in semi-arid cropping systems. Cropping intensity (relative frequency of expected harvests during a multi-year crop sequence) can also influence precipitation use. The central U.S. High Plains constitutes a distinct region with regard to historic seasonal water supply, which may relate to global atmospheric circulation patterns. The objective of this long-term cropping system study was to evaluate effects of cropping intensity and crop selection on precipitation use in a temperate semi-arid region. The focus of this analysis is crop water productivity of feed grain crops.

Procedures

Three-year crop sequences, established in 2002, consisted of a winter wheat phase (WW); a feed grain phase (corn or grain sorghum) and a broadleaf phase (spring canola, field pea, soybean or sunflower; or a non-cropped fallow period). Each phase was present each year with three replicates. Crop water use was calculated from cumulative precipitation and soil water depletion during vegetative and reproductive (grain filling) development. Canopy formation at pollen shed was assessed using a canopy light transmission method. Above-ground biomass and grain fraction were determined by hand-harvest after physiological maturity. Experimental and structural effects were analyzed

by analysis of variance and analysis of covariance (PROC GLM in SAS v. 9.4 (SAS Inst. Inc., Cary, NC)).

Results

All response variates differed among years, with differential responses for corn and grain sorghum. Cropping intensity (0.67 or 1.0) reduced all response variates except water use during vegetative growth. Water use during grain filling was the greatest source of variation observed in both above-ground biomass and grain productivity, followed by inter-annual effects and cropping intensity. The apparent yield frontier (fit by eye) indicated similar productivity increases of 1270 lb/a-in. (above-ground biomass, relative to season water use, Figure 1) and 1340 lb/a-in. (grain, relative to water use during grain filling, Figure 2). Grain yield exhibited a consistent relationship with above-ground biomass, similar for both crops (Figure 3).

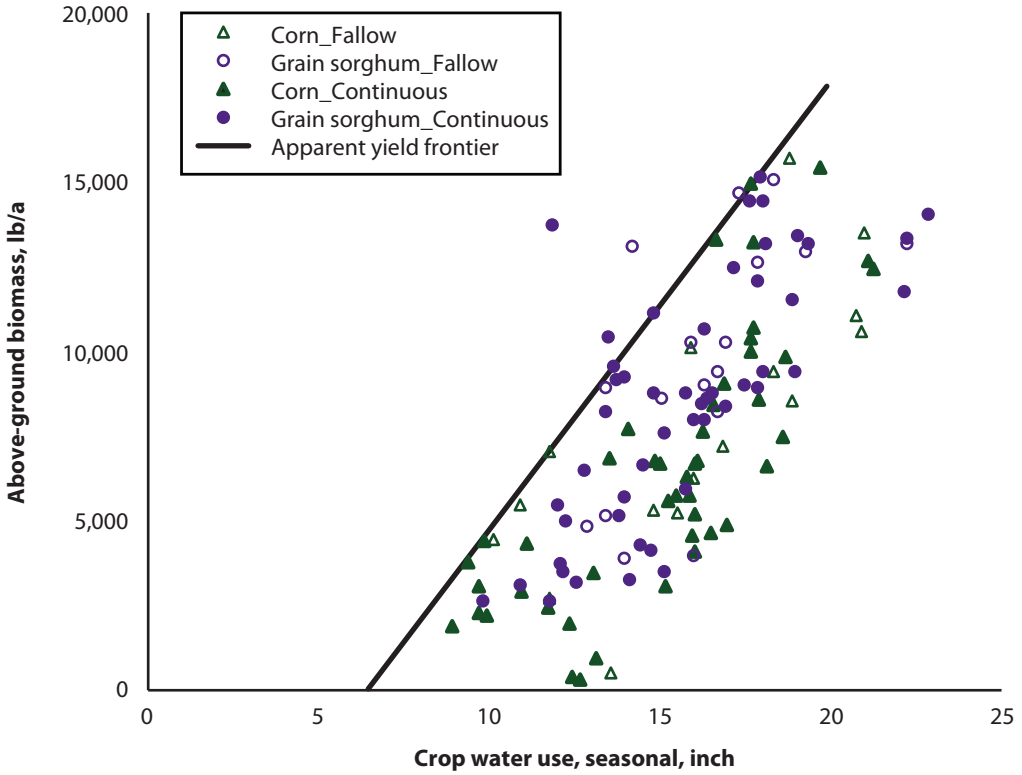

Figure 1. Above-ground biomass shown in relation to seasonal crop water use for corn and grain sorghum, grown in three-year continuous-crop or fallow crop sequences; apparent yield frontier fit by eye.

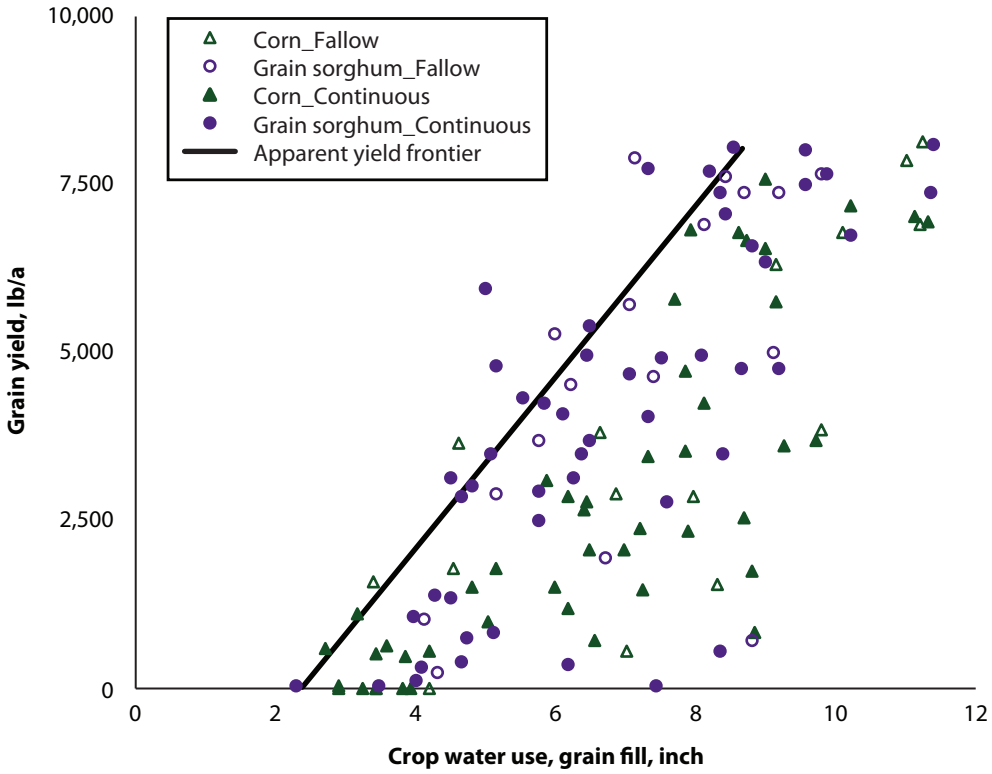

Figure 2. Grain yield shown in relation to crop water use (pollen shed through maturity) for corn and grain sorghum, grown in three-year continuous-crop or fallow crop sequences; apparent yield frontier fit by eye.

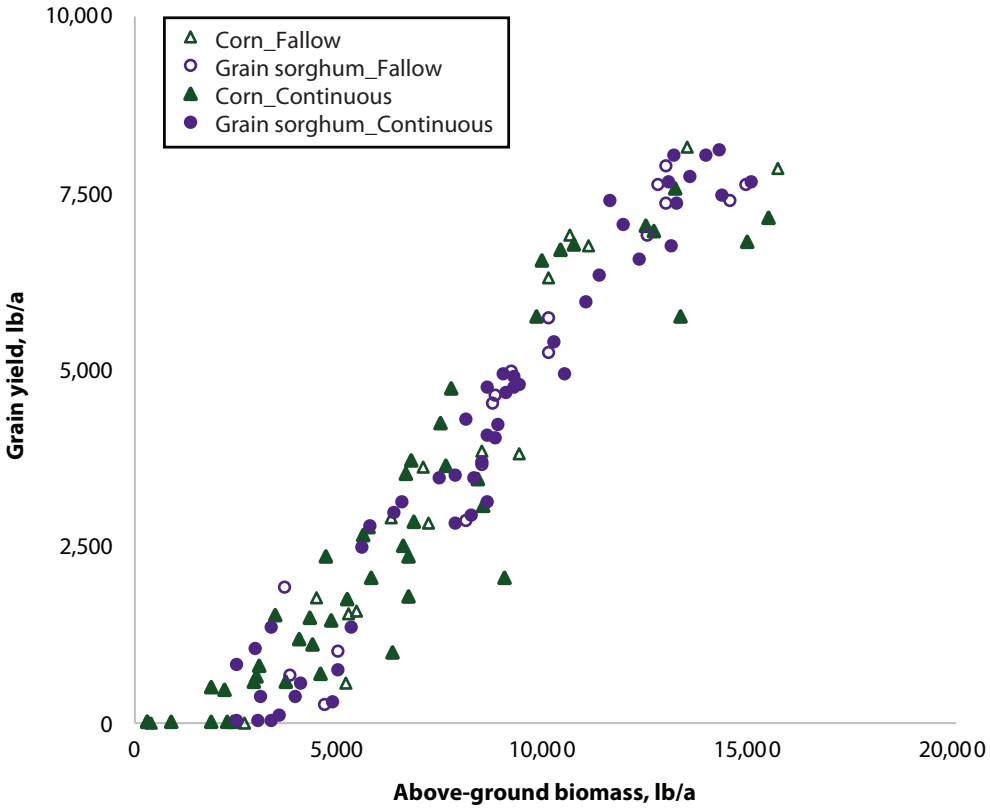

Figure 3. Grain yield shown in relation to above-ground biomass for corn and grain sorghum, grown in three-year continuous-crop or fallow crop sequences.