Field Crops Research 223 (2018) 66–74

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Skip row planting configuration shifts grain sorghum water use under dry conditions

David C. Nielsen[a,*], Merle F. Vigil[a], W. Brien Henry[b]

[a] USDA-ARS, Central Great Plains Research Station, Akron, CO 80720, United States
[b] Mississippi State University, Mississippi State, MS 39762, United States

ARTICLE INFO

Keywords:
Grain sorghum
Soil water
Water use
Skip row planting
Row configuration
Dryland cropping
Water stress

ABSTRACT

Grain sorghum (*Sorghum bicolor* L. [Moench]) is grown as a dryland crop in the semi-arid Central Great Plains. Growing the crop in a skip row configuration has been proposed as a means of delaying water use during the vegetative stage such that more water will be available to be used during the more critical flowering and grain filling stages, thereby improving yield under water stress conditions. The objective of this study was to determine if grain sorghum grown in a skip row configuration used water differently than sorghum grown in conventionally spaced rows. Grain sorghum was grown for three years at Akron, CO in three planting configurations: conventionally spaced rows 0.76 m apart, one row planted and one row skipped (P1S1), and two rows planted and two rows skipped (P2S2). Each planting configuration was planted at two seeding rates. Soil water was measured at several distances from the planted row at planting, flowering, and physiological maturity. Soil water depletion and water use were not affected by seeding rate. Grain sorghum was found to extract water at distances of 114 cm from the planted row. When growing season conditions were dry and starting soil water contents were low, skip row planting shifted the water use such that greater water use was seen during the second half of the growing season than with the conventionally spaced planting. These results support the observation of greater sorghum yields with skip row planting than with conventional row spacing during dry growing seasons.

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for com-munication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Direc-tor, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410, or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

1. Introduction

In the semi-arid environment of the Central Great Plains of the United States, crops are routinely short of available water (Robinson and Nielsen, 2015). Consequently, crop production is almost always conducted under soil water deficit conditions. These water stress conditions can be particularly detrimental to grain yield production when the stresses are severe during the sensitive reproductive and early grain filling stages (Kramer, 1983). Mastrorilli et al. (1995) reported that grain yield of grain sorghum grown in Italy was most sensitive to reproductive stage water stress that occurred during flowering. Krieg (1983) identified the period from panicle initiation to flowering as the most sensitive to water stress effects on grain yield. Garrity et al. (1982) presented field data from central Nebraska that supported the lysimeter work of Lewis et al. (1974) that concluded that sorghum grain yield was most sensitive to water deficits during the early reproductive growth period from boot through flowering (growth stages 5–6 as defined by Vanderlip and Reeves (1972)).

Kasele et al. (1994) stated that slowing the rate of soil water depletion prior to anthesis for a crop relying heavily on a limited soil

* Corresponding author at: USDA-ARS, Central Great Plains Research Station, Akron, CO 80720, United States.
E-mail address: david.nielsen@ars.usda.gov (D.C. Nielsen).

https://doi.org/10.1016/j.fcr.2018.04.003
Received 25 January 2018; Received in revised form 3 April 2018; Accepted 4 April 2018
0378-4290/ Published by Elsevier B.V.

water supply should increase the amount of available soil water remaining in the soil after anthesis. Kasele et al. (1994) and Shanahan and Nielsen (1987) earlier proposed shifting corn water use from the vegetative stage to the reproductive and grain filling stages by use of a plant growth retardant that limited vegetative development and early season water use. Cooper et al. (2014) presented both modeled and measured data showing that a drought tolerant corn hybrid used soil water at a slower rate than a drought sensitive hybrid and thereby maintained greater soil water during later, more critical growth stages. The drought tolerant hybrid used less water than the drought sensitive hybrid while producing a greater yield.

Vigil et al. (2015) hypothesized that use of skip row planting configuration (widening the distance between planted rows while maintaining the desired plant population) would change the positional availability of soil water and hence the timing of water availability and of water use. They provided data from northeastern Colorado and western Kansas indicating that sorghum yields were increased by skip row planting compared with conventionally planted sorghum with 0.76 m row spacing when yields of the conventionally planted sorghum were less than 2900 kg ha^{-1}.

In southeast Queensland, Australia, Routley et al. (2003) showed that grain sorghum planted in a skip row configuration yielded greater than conventionally planted sorghum (1.00 m row spacing) when yields of the conventionally planted sorghum were less than 2500 kg ha^{-1}, although their data set lacked data points for yields below 2300 kg ha^{-1}. They hypothesized that skip-row planting promoted grain yield through the conservation of soil water stored between the widely spaced crop rows for use by the crop after anthesis. They reasoned that skip row configurations improved yield by delaying soil water use in the center of the skip area until later in the growing season during the more critical growth stages of flowering and grain filling when water stress effects on grain yield are more pronounced. While they did provide some soil water data demonstrating the movement of the soil water depletion front over time in the P2S2 planting configuration, they did not provide data to confirm that the skip row planting shifted the water use pattern to greater water use after anthesis compared with conventionally planted sorghum.

Abunyewa et al. (2010) presented yield data for grain sorghum grown at seven Nebraska locations. They reported that the yield advantage for skip row planting configuration over conventional planting occurred when conventionally planted yields were less than 4500 kg ha^{-1}. In their study they reported soil water content data at several dates during the growing season, but unfortunately the measurements were made only at the center of the inter-row spaces, which meant measurements were at 38 cm from the planted row for the conventionally planted configuration, 76 cm from the planted row for the P1S1 configuration, and 114 cm from the planted row for the P2S2 configuration. Consequently an evaluation of the true effects of skip row planting on soil water depletion timing across the inter-row space was not possible.

Lyon et al. (2009) analyzed 23 data sets acquired over a three-yr period from Nebraska, western Kansas, and northeastern Colorado and found that corn yields were improved with skip row planting when conventionally planted corn yields were less than 4700 kg ha^{-1}. However, no soil water data were presented that would support the hypothesis that skip row planting had shifted the water use pattern to greater water use during the more critical flowering and grain filling periods. Mesfin et al. (2014) reported that both corn and sorghum yields in Ethopia were not affected by skip row planting but speculated that skip row yields would be greater than conventionally planted yields under conditions of greater late season soil water deficits.

The objectives of this study were to determine if grain sorghum has sufficient lateral rooting capacity to extract soil water from the wide inter-row space when either P1S1 or P2S2 planting configuration is used and, if so, whether either P1S1 or P2S2 planting configuration alters the crop water use pattern such that greater water use occurs in the second half of the growing season compared with conventional planting with uniform 0.76 m row spacing.

2. Materials and methods

Grain sorghum water use data were collected during the 2006, 2007, and 2008 grain sorghum growing seasons at the USDA-ARS Central Great Plains Research Station (40°09′ N, 103°09′ W, 1383 m elevation above sea level) located 6.4 km east of Akron, CO. The soil was a Weld silt loam (Aridic Argiustolls) (https://soilseries.sc.egov.usda.gov/OSD_Docs/W/WELD.html, accessed 28 December 2017). Individual plot size was 9.14 by 27.43 m with north-south row direction. Each year of the study had four replications of each of the six treatment combinations (three planting configurations, two plant populations) which were randomly assigned within each replication. The treatment variables were seeding rate (61,750 and 123,500 seeds ha^{-1}) and planting configuration. Three planting configurations were tested:

1. conventional planting with every row planted and 0.76 m row spacing
2. plant one skip one (P1S1) with every other row planted, essentially creating a treatment with 1.52 m row spacing
3. plant two skip two (P2S2) with a pair of planted rows 0.76 m apart separated from another pair of planted rows by an unplanted skip of 2.29 m

Because the two seeding rates used were the same in each planting configuration, there was greater in-row plant population for the skip row plantings compared with the conventional planting. For example, with the low population, seeds were 21.3 cm apart in a row of the conventional planting 10.6 cm apart for the skip row plantings. Plots were planted with Pioneer Hybrid 8925, an early maturity hybrid (rated as 58 days to flowering, https://www.pioneer.com/home/site/us/products/sorghum/seed-guide, accessed 21 Dec 2017) suitable for dryland production in Colorado. Plots were planted in late May or early June (Table 1). Winter wheat was grown prior to the 2006 and 2007 grain sorghum crops, and grain sorghum was grown prior to the 2008 sorghum crop.

Soil water was measured in each plot at 0.3-m intervals with a neutron probe (Model 503 Hydroprobe, CPN International, Martinez, CA) via the installation of neutron probe access tubes in each plot. The soil water measurement depth intervals were 0.0–0.3 m, 0.3–0.6 m, 0.6–0.9 m, 0.9–1.2 m, 1.2–1.5 m, and 1.5–1.8 m, with the neutron probe source centered on each interval. The neutron probe was calibrated against gravimetric soil water samples taken in the plot area. Gravimetric soil water was converted to volumetric water by multiplying by the soil bulk density for each depth. Bulk density was determined from the dry weight of the soil cores (38 mm diameter by 300 mm length) taken from each depth at the time of neutron probe access tube installation. The soil water measurement sites relative to row positions for the various planting configurations are shown in Fig. 1. There were two measurement sites for the conventional planting, three measurement sites for the P1S1 planting, and five measurement sites for the P2S2 planting. All measurement sites were located near the center of each plot. Distance between soil water measurement sites

Table 1
Dates of grain sorghum planting and soil water measurements in 2006, 2007, and 2008 at Akron, CO.

Year	Planting Date	Date of Beginning Soil Water	Date of Flowering Soil Water	Date of Ending Soil Water
2006	26 May	8 June	8 August	8 November
2007	11 June	25 June	20 August	9 October
2008	11 June	27 June	13 August	24 October