Agricultural Water Management 172 (2016) 40–50

Contents lists available at ScienceDirect

Agricultural Water Management

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

Soil water improvements with the long-term use of a winter rye cover crop

Andrea D. Basche[a,1], Thomas C. Kaspar[b], Sotirios V. Archontoulis[a], Dan B. Jaynes[b], Thomas J. Sauer[b], Timothy B. Parkin[b], Fernando E. Miguez[a,*]

[a] Department of Agronomy, Iowa State University, Agronomy Hall, Ames, IA 50011, United States
[b] National Laboratory for Agriculture and the Environment, USDA-ARS, 2150 Pammel Drive, Ames, IA 50011, United States

ARTICLE INFO

Article history:
Received 28 December 2015
Received in revised form 26 March 2016
Accepted 8 April 2016
Available online 26 April 2016

Keywords:
Midwest Corn Belt
Cover crop
Soil water storage
Plant available water
Water content at field capacity
Plant growth

ABSTRACT

The Midwestern United States, a region that produces one-third of maize and one-quarter of soybean grain globally, is projected to experience increasing rainfall variability. One approach to mitigate climate impacts is to utilize crop and soil management practices that enhance soil water storage and reduce the risks of flooding as well as drought-induced crop water stress. While some research indicates that a winter cover crop in maize-soybean rotations increases soil water availability, producers continue to be concerned that water use by cover crops will reduce water for a following cash crop. We analyzed continuous in-field soil water measurements from 2008 to 2014 at a Central Iowa research site that has included a winter rye cover crop in a maize-soybean rotation for thirteen years. This period of study included years in the top third of the wettest on record (2008, 2010, 2014) as well as drier years in the bottom third (2012, 2013). We found the cover crop treatment to have significantly higher soil water storage at the 0–30 cm depth from 2012 to 2014 when compared to the no cover crop treatment and in most years greater soil water content on individual days analyzed during the cash crop growing season. We further found that the cover crop significantly increased the field capacity water content by 10–11% and plant available water by 21–22%. Finally, in 2013 and 2014, we measured maize and soybean biomass every 2–3 weeks and did not see treatment differences in crop growth, leaf area or nitrogen uptake. Final crop yields were not statistically different between the cover and no cover crop treatment in any of the seven years of this analysis. This research indicates that the long-term use of a winter rye cover crop can improve soil water dynamics without sacrificing cash crop growth in maize-soybean crop rotations in the Midwestern United States.

1. Introduction

There is a need to maintain or improve soil productivity in the 21st century in light of climate change and increasing agricultural demands (Amundson et al., 2015; Lal et al., 2011). Currently, most of the Midwestern United States, where one-third of global maize (*Zea mays* L.) and one-quarter of global soybean (*Glycine max* (L.) Merr.) are grown, is usually not limited in water or soil resources and this, in part, contributes to its immense productivity (FAOSTAT, 2015; USDA-NASS, 2014). However, climate projections point to increased rainfall variability (Daniel, 2015; Winkler et al., 2012) beyond what has already been observed over the last several decades (Groisman et al., 2012; Mallakpour and Villarini, 2015) which threatens the soil and water resources currently available in the region. Further, these predicted climate changes are expected to reduce crop yields, especially for maize in the Midwestern Corn Belt, without changes to current management (Challinor et al., 2014; Walthall et al., 2013; Wang et al., 2015). However, other research indicates that the impacts of climate change can be reduced with conservation practices in this region (Basche et al., 2016; Panagopoulos et al., 2014; Van Liew et al., 2013).

Employing management practices that improve soil water dynamics (i.e. processes such as increased storage and enhanced infiltration) is one approach to mitigate the impacts of increased rainfall variability, on a field and landscape scale. Several alternative cropping systems have been tested to determine their impacts

---

* Corresponding author.
E-mail addresses: abasche@ucsusa.org (A.D. Basche), tom.kaspar@ars.usda.gov (T.C. Kaspar), sarchont@iastate.edu (S.V. Archontoulis), dan.jaynes@ars.usda.gov (D.B. Jaynes), tom.sauer@ars.usda.gov (T.J. Sauer), tim.parkin@ars.usda.gov (T.B. Parkin), femiguez@iastate.edu (F.E. Miguez).

[1] Present address: Union of Concerned Scientists Food and Environment Program, 1825 K St. NW, Suite 800, Washington, D.C. 20006, United States.

http://dx.doi.org/10.1016/j.agwat.2016.04.006

Table 1
Management dates and operation information during the seven years of this analysis.

Year	Cash Crop	Cover Crop Termination Date	Cash Crop Planting Date	Harvest Date	Cover Crop Planting Date	Total N applied kg ha^{-1}
2008	Maize	29-Apr	14-May	28-Oct	29-Oct	198
2009	Soybean	21-May	22-May	28-Sep	28-Sep	
2010	Maize	19-Apr	29-April	16-Sep	17-Sep	198
2011	Soybean	5-May	18-May	29-Sep	30-Sep	
2012	Maize	23-Apr	4-May	19-Sep	4-Sep[a]	197
2013	Soybean	13-May	23-May	20-Oct	4-Sep[a]	
2014	Maize	10-Apr	6-May	17-Oct	9-Sep[a]	196

[a] Winter rye cover crop was broadcast seeded before maize and soybean harvest. All other seasons cover crop was seeded with a drill post harvest.

on soil water dynamics in the Midwestern United States. Qi et al. (2011) found that a cereal rye (*Secale cereale* L.) cover crop increased soil water storage when added to a maize-soybean cropping system. Brye et al. (2000) found that a prairie ecosystem maintained higher soil water content deeper in the soil profile despite larger evapotranspiration and less drainage than a maize cropping system. Further, Daigh et al. (2014b) and Qi and Helmers (2010) found significantly lower cumulative drainage with a cover crop. There is also a body of evidence that supports the ability of cover crops to increase soil carbon or soil organic matter (Kaspar and Singer, 2011; McDaniel et al., 2014; Moore et al., 2014; Poeplau and Don, 2015) and to improve the soil physical properties which enhance soil water dynamics (Daigh et al., 2014a; Steele et al., 2012; Villamil et al., 2006). Further, there is a complex interaction of soil physical and chemical properties that contribute to soil water storage capacity, including soil organic matter concentration, aggregation and porosity (Emerson, 1995; Hudson, 1994; Kay, 1998). Growing an over winter cover crop between the harvest and planting of maize and soybeans does not take acres out of production and is one strategy for mitigating environmental impacts of Midwestern agriculture (EPA, 2008; INRS, 2012). However, survey data (SARE-CTIC, 2013, 2014) and leading practitioners (Carlson and Stockwell, 2013) indicate that producers are concerned that cover crops may reduce water availability for the following cash crop. Thus, even though cover crops provide many benefits, producers might be reluctant to adopt them if they perceive an increased risk of water stress for the cash crop.

Therefore to increase adoption of cover crops it is important to determine (and demonstrate in the long-term) whether cover crop water use reduces water availability for the following cash crop. It is also important to improve our understanding of how a cover crop alters water dynamics over wetter and drier seasons to evaluate their benefits in mitigating rainfall variability impacts. Our research questions were: How is soil water content affected by a winter rye cover crop? How is soil water storage affected by the cover crop? Which soil water retention properties are affected by the cover crop? Does the water use from the cover crop negatively impact maize and soybean growth? To answer these questions, we analyzed an extensive dataset from a long-term field site that included seven years of continuous soil water content measurements recorded over years with very different weather patterns and treatments with and without a cereal rye winter cover crop. We also collected crop growth data and soil hydraulic property measurements from the most recent two years of the experiment.

2. Materials and methods

2.1. Field site

The field site is located in Boone County, IA (42.05°N, 93.71°W) and was established in 1999. It is a randomized complete block design with four replications and includes different tillage, nitrogen management, and cover crop treatments within a maize-soybean cropping system, where maize is planted in the spring of the even-numbered years and soybeans in the spring of the odd-numbered years. This study evaluated the differences between a no-till winter rye cover crop treatment and a no-till control without a cover crop. The winter rye plots were first established within the maize-soybean rotation in fall 2000 and it represents a long-term record of winter rye impacts within the predominant cropping system found across the Midwest. The winter rye cover crop was established either by drilling after harvest of maize and soybeans in the fall (2007–2011) or by broadcast seeding before harvest in the late summer (2012–2014). Broadcast seeding was utilized in the more recent years of the experiment to examine the effect of earlier planting as well as to evaluate seeding methods that could be easier for farmers to implement. Further information on the site management can be found in Table 1, as well as in Kaspar et al. (2007) and Kaspar et al. (2012).

2.2. Soil water and soil physical properties analysis

Volumetric soil water content (θ) was estimated using an impedance soil moisture sensor Theta Probe (Model Type ML2x, Delta-T Devices, Cambridge, United Kingdom) hourly at depths of 5, 10 and 15 cm from 2008 to 2011 and at 5, 15 and 30 cm from 2012 to 2014. The depth of sensors was changed in the later experiment years to try to better differentiate cover crop differences at the three measurement depths and to extend the measurements deeper into the soil profile. Voltage measurements were converted to a dielectric constant then to volumetric water content, using the calibration equation for Des Moines Lobe soils based on the work of Kaleita et al. (2005). The Theta Probes were installed at two locations in three of the four experimental replications, vertically at 5 cm and horizontally at the lower depths. Sensors were removed only when necessary to accommodate field machinery operations and were replaced immediately following completion. Soil water storage was calculated by sectioning the available depths (0–5 cm, 5–10 cm, and 10–15 cm in 2008–2011; 0–5 cm, 5–15 cm and 15–30 cm in 2012–2014), assuming that the soil water content (θ) level was equal throughout that depth layer and multiplying the depth (mm) by corresponding volumetric soil water content level (mm^3 mm^{-3}). The cumulative soil water storage (SWS) values were derived by calculating the sum of the individual storage values for the three available depths.

We focused our analysis of soil water content on treatment differences on individual days during two key periods of the year when the cover crop might have important effects on soil water dynamics (Section 3.1). The first period was during the spring (between early April and mid-May) about ten days before the cover crop was terminated through about ten days after the cash crop was planted. These dates varied depending on whether maize or soybeans were the cash crop that year. The second period was during summer (mid-July through the end of August), when maize and soybeans enter reproductive growth and crop water demand is critical for optimizing yield (Claassen and Shaw, 1970a,b; NeSmith and Ritchie, 1992). We focused our analysis of treatment effects of soil water storage