G Model
AGWAT-4376; No. of Pages 9

ARTICLE IN PRESS

Agricultural Water Management xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Agricultural Water Management

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

No-till and direct seeding agriculture in irrigated bean: Effect of incorporating crop residues on soil water availability and retention, and yield

João V.R.S. Souza[a,*,1], João C.C. Saad[a,1], Rodrigo M. Sánchez-Román[a,1], Leonor Rodríguez-Sinobas[b,2]

[a] Universidade Estadual Paulista Júlio de Mesquita Filho, Faculdade de Ciências Agronômicas de Botucatu, Brazil
[b] Research Group "Hydraulics for Irrigation"of the Technical University of Madrid, Spain

ARTICLE INFO

Article history:
Received 15 September 2015
Received in revised form
23 December 2015
Accepted 7 January 2016
Available online xxx

Keywords:
TDR
Crop residues
Common bean
Soil moisture
Water retention
Yield

ABSTRACT

Brazil is one of the top world producers of the staple commodity common bean (*Phaseolus vulgaris* L.). Irregular distribution of rainfall and the lack of rain during the crop reproductive phases affect its yield and increase the demand of water for irrigation. However, in recent years, water resources have decreased and water saving has become an issue. Thus, soil management techniques, which reduce evaporation, and efficient irrigation programming, through the monitoring of soil water content, could be adopted in water scarcity scenarios. This study assesses the effect of crop residues management (incorporated IR or left on soil surface NR) in soil water availability (and its retention in the soil pore space), and yield in common beans cultivated under no-till and directly seeded in an irrigated farm located southwest of São Paulo state. Soil water content was monitored with TDR probes installed within the 0–20 cm layer and its retention was assessed through the soil water retention curve. For the same irrigation management, the IR led to soil water content was lower than NR but both soil managements had similar available water and their demand of water for irrigation was similar. For the same soil water content, NR soils could hold it tightly in the pore space and the root plant system would require higher energy to absorb it. Then, it is foreseen that the root system in IR soils will be shallower than in NR soils, since it will withdraw water easily within the first 20 cm, however, in NR, the roots will extend deeper searching for available water. Considering 40 kPa as a threshold value, the plants suffered water stress during all crop cycle at the same physiologic stages in both soils. The variables studied to assess yield presented no-statistical significance in the *T* test at significance level of 0.05.

1. Introduction

The benefits of conservation agriculture, comprising no-till as well as reduced tillage practices (subsoiling, deep ploughing), have long been recognized, and they are accentuated in combination with crop residues application. Crop residues on the soil surface protect the soil and reduce its erosion (Boulal et al., 2011; Brouder and Gomez-Macpherson, 2014) and runoff (Buschiazzo et al., 1998; Thomas et al., 2007). They also enhanced fertility and soil quality mainly by increasing soil organic matter (Bhattacharyya et al., 2012, 2013; Jemai et al., 2013; Ladha et al., 2009; Verhulst et al., 2010), which, in turn, may increase soil carbon sequestration (Palm et al., 2014).

Conservative agriculture systems also improve aggregate stability (Blanco-Canqui and Lal, 2007; Keller et al., 2007) and total porosity (Jemai et al., 2013; Lipiec et al., 2006; Mulumba and Lal, 2008) and as a consequence, soil moisture content increases (Govaerts et al., 2007; Gruber et al., 2011; Sharma et al., 2011) as well as water content availability (Bescansa et al., 2006; Jemai et al., 2013). In addition, infiltration (Bhattacharyya et al., 2006;

* Corresponding author at: Universidade Estadual Paulista Júlio de Mesquita Filho, Faculdade de Ciências Agronômicas de Botucatu, Rua José Barbosa de Barros, no. 1780, Fazenda Lageado, Caixa-postal: 237, 18603970 Botucatu, SP, Brasil.
E-mail addresses: joao.vrs@outlook.com (J.V.R.S. Souza), joaosaad@fca.unesp.br (J.C.C. Saad), rmsroman@fca.unesp.br (R.M. Sánchez-Román), leonor.rodriguez.sinobas@upm.es (L. Rodríguez-Sinobas).
[1] Universidade Estadual Paulista Júlio de Mesquita Filho, Faculdade de Ciências Agronômicas de Botucatu. Rua José Barbosa de Barros, no. 1780, Fazenda Lageado, Caixa-postal: 237, 18603970 Botucatu, SP, Brasil.
[2] Research Group "Hydraulics for Irrigation", Technical University of Madrid Agricultural Engineering School, Ciudad Universitaria, 28040 Madrid, Spain.

http://dx.doi.org/10.1016/j.agwat.2016.01.002
0378-3774/

Please cite this article in press as: Souza, J.V.R.S., et al., No-till and direct seeding agriculture in irrigated bean: Effect of incorporating crop residues on soil water availability and retention, and yield. Agric. Water Manage. (2016), http://dx.doi.org/10.1016/j.agwat.2016.01.002

Nielsen et al., 2009), water retention (Datiri and Lowery, 1991) and hydraulic conductivity (Benjamin, 1993) are improved as well.

In Brazil, a surface of about 25,000,000 ha was cultivated under non tillage practices in 2007. Farmers have adopted this technology not only due to environmental issues (erosion control, improvement of soil fertility), but mainly due to its economical aspects (less labor work, higher profits) (Casão Junior et al., 2012). Sorrenson and Montoya (1984) highlighted that non tillage was the most cost effective means of controlling erosion in Brazil.

Common bean (*Phaseolus vulgaris* L.) is the most important eating legume worldwide and is a staple commodity in developing countries (Broughton et al., 2003). Brazil is the largest producer with 17.3% of the world production, followed by India (16.4%), Myanmar (9.6%), China (6.7%), United States (6.3%) and Mexico with 5.4% (FAO, 2009).

Approximately, 60% of the world's common beans cultivated areas are concentrated in regions that suffer water scarcity, where the crop is under water stress, the second major cause of yield loss (Singh, 1995). Drought can modify leaf development and thus, affect grain yield by reducing the active leaf area for photosynthesis (Guimarães, 1996; Fancelli and Dourado Neto, 1991). Plant height, leaf area index, number of seeds per pod, number of pods per plant and yield are reduced in plants suffering from water stress (Monteiro et al., 2010), although the number of pods per plant was the most sensitive variable to maintain a potential yield (Guimarães et al., 2011; Miorini et al., 2011). Likewise, the bean root system develops mostly in the upper soil layer enhancing the sensitivity of the crop to water stress and reinforcing the role of irrigation water supply for proper crop development during scarce rainfall periods (Carlesso et al., 2007). The response of common bean species to different water regimes in controlled environment showed that water consumption in plants with highest irrigation frequency was smaller than those less frequently irrigated, which suggested that they suffered some stress (Bourgault and Smith, 2010). Likewise, the efficiency of crop water used for leaf area development was different in the two species studied (common beans and mud beans). In addition, under low soil moisture conditions, plants developed a conservative water use by lowering maximum transpiration rates.

Common beans in Brazil are cultivated nationwide in different sowing dates and under different climatic conditions alternating water surplus and deficit periods. Since crop is sensitive to water stress, irrigation is needed in regions where rainfall is unevenly distributed to maintain yield and farmersí benefits (Didonet, 2005; Guimarães et al., 2011). Farmerís revenue in irrigation areas is about 70% higher than in rain fed crops (Silveira et al., 2001) although under stress conditions, a 20% yield decrease has been reported by Miorini et al. (2011)

In Brazil, irrigation demands about 72% of the water (Alves, 2015) and water resources are increasingly scarce every year. Considering this scenario, we can expect that water resources will be less available for irrigated agriculture and competition for water will increase in the near future. Within this context, conservative agriculture (no-till, direct seeding) along with a proper soil water content monitoring could be key factors for saving water by reducing evaporation and improving irrigation programming. In this regard, studies on conservative agriculture in common bean, mainly in Brazil, are numerous, but none has compared the effect of crop residue management on water availability and retention in the soil pore network during the crop cycle.

The objective of this study was to evaluate the effect of crop residues management (incorporated and non-incorporated into the soil) on soil water availability (and its retention in the soil pore space), during all the phenology stages, and yield in common beans cultivated under non tillage conditions and directly seeded irrigated agriculture.

2. Materials and methods

2.1. Experimental site

The field experiments were conducted at "Olhos D'água" farm (latitude: 23°33′21.14″S; longitude: 48°52′43.86″W) in the southwestern region of the State of São Paulo (Brazil). The farm is a member of the No-till and Planting in the Straw Irrigators Association of South western São Paulo, ASPIPP.

The farmer follows no-till and direct seeding farming, leaving the crop residue from the previous harvest over the soil, since 2007. In this year, he ploughed the soil and made deep harrows adding calcium carbonate (Ca_2C0_3) to maintain soil pH at 5.5. These tasks are performed once every ten years. Maize, common beans, soybeans and wheat are the main cultivated crops.

For this study, an irrigated area of 20 ha was selected with a crop rotation of maize-common beans.

2.2. Water application by the irrigation system

The area is irrigated in sectors of 180° by a 361.75 m long center pivot (Lindsay, Zimmatic model) which is hold by seven towers. The system operates with an inlet pressure head of 50.05 m and a discharge of 260 m^3 h^{-1}. Considering these conditions, a field evaluation of the irrigation system was performed following the ABNT-NBR 14244 (ABNT, 1998). The uniformity of water application was calculated by the Christiansen Uniformity Coefficient—CUC as:

$$\mathrm{CUC} = \left(1 - \frac{\sum_{i=1}^{N} |H_i - H_m|}{N \times H_m}\right) \times 100 \quad (1)$$

where H_i is the height of water collected in the collector (mm), H_m is the average water height from all the collectors (mm), and N is the number of collectors.

The irrigation events (water depth and time) are programmed by the farmer to supply the crop water requirements estimated with the data monitored in the farm's weather station. However, a limit of 16 mm water depth per irrigation is imposed, considering the pumping system specifications, the number of center pivots with simultaneous irrigation and the cost of energy, which varies along the day.

2.3. Field preparation

This study evaluated the performance of two different soil management practices: crop residues left on the soil (non-incorporated residues NR) and incorporated in the soil (IR). Thus, two parallel 6 m width soil strips were selected along the center pivot radius. Each strip followed a randomly alternation of areas with maize residues left on the soil (NR) and incorporated in the soil (IR) as it is described in Fig. 1. Thus, the pattern of alternating NR and IR areas in both strips was opposite. The length for each area was the spacing between the center pivot towers (50 m) which was considered adequate for a uniform crop residues' incorporation.

A 28-inch disc harrow was used for the incorporation of maize residues at 17 cm depth, 22 days before planting. Five successive passes of the disc harrow were necessary to fully incorporate the residues in the selected areas. Then, a leveled harrow disaggregated soil clods and leveled up the soil surface.

2.4. Soil characteristics

Soil texture was determined in three soil samples collected along the center pivot radius at two layers of 0–20 cm and 20–40 cm. The samples from both layers were analyzed, however,