Agricultural Water Management 204 (2018) 138–148

Contents lists available at ScienceDirect

Agricultural Water Management

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

The ridge furrow cropping technique indirectly improves seed filling endogenous hormonal changes and winter wheat production under simulated rainfall conditions

Shahzad Ali[a,b,1], Yueyue Xu[a,b,1], Irshad Ahmad[a,b], Qianmin Jia[a,b], Huang Fangyuan[a,b], Ihsanullah Daur[c], Ting Wei[a,b], Tie Cai[a,b,*], Xiaolong Ren[a,b], Peng Zhang[a,b], Zhikuan Jia[a,b,*]

[a] Institute of Water Saving Agriculture in Arid Areas of China, Northwest A&F University, Yangling, Shaanxi 712100, China
[b] Key Laboratory of Crop Physi-ecology and Tillage Science in North-western Loess Plateau, Ministry of Agriculture, Northwest A&F University, Yangling, Shaanxi 712100, China
[c] Department of Arid Land Agriculture, King Abdulaziz University, Jeddah, Saudi Arabia

ARTICLE INFO

Keywords:
Limited irrigation
Rainfall
Seed filling process
Hormone
Wheat yield
Planting patterns

ABSTRACT

We sought to study the effects of the ridge furrow (RF) rainwater collecting technique on winter wheat seed filling with limited irrigation under simulated rainfall concentrations and its correlation with hormonal changes. The RF system was compared to traditional flat planting (TF) with two limited irrigation levels (150, 75 mm) under three simulated precipitation concentrations (1: 275, 2: 200, 3: 125 mm) during 2015–2017 experimental years. The results indicated that the RF_{150} treatment with 125 mm rainfall, a significantly improved seed filling rate was observed in the basal and upper seeds. The RF_{150} treatment with 200 mm precipitation also significantly improved the single seed weight and seed filling rate in the basal and upper seeds. In contrast, the RF system with 275 mm precipitation showed no significant influence on the seed filling rates and seed weight of basal and upper seeds under either limited irrigation level. The RF system at 125 and 200 mm simulated rainfall level exhibited increased (IAA) indole-3-acetic acid and (Z) zeatin + (ZR) zeatin riboside contents. The RF system under 150 mm limited irrigation showed decreased (ABA) abscisic acid and gibberellic acid (GAs) in the basal and upper seeds. The RF system with 275 mm precipitation had no significant influence on the IAA, Z + ZR, ABA and GA contents in the basal and upper seeds under either limited irrigation levels. The IAA, Z + ZR, ABA and GAs in the seeds s were positively correlated with the maximum and mean seed-filling rate and the maximum seed weight. Our results demonstrate that the $RF2_{150}$ treatment significantly improved the soil water contents and soil respiration rate, thereby regulating the wheat seed filling rate and creating hormonal changes. These fluctuations significantly affected the agronomic properties of winter wheat production in semi-arid regions.

1. Introduction

Winter wheat yield in rain-fed areas of China is highly dependent on precipitation, although it is erratic and insufficient in these regions (Nagaz et al., 2012). The majority of rainfall occurs during the monsoon season with 68% of the yearly precipitation falling from June to September in semi-arid regions of China (Wang et al., 2015). The monsoon spells do not overlap with the wheat growing season and water scarcity is often a limitation to growth (Li and Gong, 2002). Furthermore, the annual evaporation in rain-fed areas of China is more than 830 mm, resulting in severe drought conditions throughout the winter wheat growing period (Zhang et al., 2011). In order to deal with inadequate water resources and to increase wheat production in these areas, it has been important to develop water saving agricultural techniques to maximize utilization of the erratically available rainwater and increase soil moisture content (Ren et al., 2016). Previous studies have suggested that ridge covering materials including plastic mulch and biodegradable mulch are able to conserve rainwater, decrease evaporation and improve soil moisture content and soil respiration rate, in turn enhancing winter wheat water usage efficiency (WUE) (Martinez et al., 2011).

Overall, it is difficult to improve plant growth in semi-arid areas of China due to water shortages (Li et al., 2016). Currently, the ridge furrow precipitation harvesting (RF) technique has been implemented

* Corresponding authors at: Institute of Water Saving Agriculture in Arid Areas of China, Northwest A&F University, Yangling, Shaanxi 712100, China.
E-mail addresses: sdauct@126.com (T. Cai), jiazhk@126.com (Z. Jia).
[1] These authors have contributed equally to this research work.

https://doi.org/10.1016/j.agwat.2018.03.031
Received 22 September 2017; Received in revised form 22 February 2018; Accepted 19 March 2018
Available online 30 April 2018
0378-3774/ © 2018 Elsevier B.V. All rights reserved.

in rain-fed areas of China to solve water shortage issues (Jia et al., 2006). The RF technique includes ridges and furrows, where the ridges are covered with a plastic film for use as a precipitation collecting zone and the furrow is used as the sowing zone (Hu et al., 2014). The RF technique significantly improves soil water storage by saving water during light intensity precipitation and preserving surface runoff during high intensity rainfall (Li et al., 2001). The RF technique decreases soil temperature as well as prolongs the duration of water availability for the winter wheat growing season (Li et al., 2016). Deng et al. (2006) reported that the RF system improves water content by 11–15% in the 200 cm soil layer depth and increases grain yield 75% under precipitation of 230–340 mm compared to traditional flat (TF) cultivation. However, the biological yield, water use efficiency and seed yield of corn were not significantly enhanced when rainfall was more than 440 mm.

Water shortage during the winter wheat crop's flowering and seed-filling stage can cause significant grain yield decreases. These decreases are mainly due to oxidative damage as a result reducing seed set and sink capacity of the plant. It has been shown that the RF planting model can offset this damage by preventing water shortage (Xie et al., 2008; Kang et al., 2002). However, during the flowering and seed-filling stages water deficiency is often unavoidable (Guo et al., 2014). Limited irrigation (LI) coupled with the RF system may offer a solution for supplying water during critical growth stages, significantly increasing grain yield and soil respiration rate (Ali and Thei, 2004; Tang et al., 2011). It is important to note that an unnecessary supply of irrigation water can lead to high rates of evapotranspiration and biomass accumulation, and does not significantly increase grain yield (Geerts et al., 2008). It has been shown that the soil respiration rate improves with increasing irrigation, but over-irrigation will suppress the soil respiration rate (Wang et al., 2009). The RF technique with varied precipitation conditions and limited irrigation that affects the biochemical mechanism and winter wheat production has not been clarified.

The potential yield of winter wheat can be divided into three main units: spike plant^{-1}, seed weight and seeds spike^{-1}. In current semi-arid regions, the maximum yield and seed filling development in winter wheat have been affected by fluctuating rainfall and the yield potential outputs have become unpredictable (Ali et al., 2016). It is important to understand how the RF system influences wheat seed filling and the primary biochemical mechanisms during this developmental stage when various rainfall amounts and limited irrigation are applied. Winter wheat seed filling is controlled by several factors, including plant hormones that have been shown to have a significant role in modifying seed filling progress (Yang et al., 2006). Higher abscisic acid (ABA) content in winter wheat seeds is linked with maximum seed filling rate (Yang et al., 2006). The zeatin + zeatin riboside (Z + ZR), phytohormones of the cytokinin family, contents in developing winter wheat seeds temporarily enhance fertilization during kernel setting and endosperm cell division (Morris et al., 1993). The GAs content in rice seeds is also associated with the early seed filling stage (Gao et al., 2000), and the maximum and mean seed filling rate were positively associated with GAs concentrations in rice seeds (Yang et al., 2001). Additionally, the IAA content in basal seeds has been found to be higher than that of upper seeds during the early seed filling stage of rice (Wu et al., 2008).

These studies have shown that plant hormonal changes significantly affect the seed filling process of rice crops. However, the hormonal variation between spike seed positions and the correlation between seed filling and hormonal changes induced by the RF system remains unclear. In the present study, various simulated rainfall and limited irrigation levels under different planting patterns were used during the winter wheat growth stage, and the hormonal changes in the grains during grain filling were measured. The objective of this study was to investigate the relationship between the effect of RF technique under simulated precipitation and limited irrigation on grain filling of winter wheat and the soil water content and to determine how the changes in endogenous hormones in the developing grains of winter wheat under RF technique are related to the grain-filling process.

2. Materials and methods

2.1. Study site description

Field research was carried out from 2015 to 2017 at the Northwest A&F University, Yangling, Shaanxi Province, China (34°20′N, 108°24′E) and the experimental site was 466.7 m above sea level. The climate at the trial site was a warm, temperate and semi-arid; with an annual mean temperature were 12.9 °C and the annual average minimal and maximal temperatures at −17.4 °C and 42 °C, respectively. The annual rainfall and evaporation rate were 550 mm and 1753 mm, respectively. The daylight was 2196 h per year, with frost-free period of 220 days per year, respectively. The mean soil bulk density was 1.37 g cm^{-3}. The average means of two year available NPK were 39.4 mg kg^{-1}, 7.98 mg kg^{-1} and 99.94 mg kg^{-1}, respectively. The soil organic matter and pH of the 0–20 cm soil layer depth were 10.88 g kg^{-1} and 7.80, respectively.

2.2. Experimental design and treatments

The field study was performed under the waterproof sheds. The inside shed size was 3 m (height) × 15 m (width) × 32 m (length). The mobile waterproof sheds were used to manage natural rainfall on the raining days. The research trial consisted of two planting patterns (RF: ridge furrow rainfall collection, TF: traditional flat planting) with three precipitation levels (1: 275 mm, 2: 200 mm, 3: 125 mm) and two limited irrigation (150 mm and 75 mm) levels in a randomized complete block design (RCBD) with four replications. Half of the limited irrigation was supplied on December 12, 2015 and December 15, 2016 (before the re-wintering) and the other half was supplied on March 28, 2016 and March 25, 2017 at jointing stage with the help of a precise water meter. The limited irrigation volumes for 150 and 75 mm were measured according to the irrigation area. The irrigation area for the TF planting treatment was 6.3 m^2 (2.0 m × 3.15 m) and the irrigation volume was 0.95 and 0.47 m^3 under 150 and 75 mm. The irrigation area under the RF technique, of the two furrows was 3.78 m^2 (1.2 m × 3.15 m) and the irrigation volume of the two furrows was 0.57 and 0.28 m^3, respectively. The RF technique used a height of ridge was 15 cm with furrow and ridge widths of 60:40 cm. A thickness of 0.008 mm of plastic film was used to cover all ridges with hidden edges of 4–5 cm deep in the soil. Four rows of wheat were sown in furrow. The width and length of each treatment was 2.0 m × 3.15 m, and weeds were controlled manually during each growing season of winter wheat crop.

Wheat cultivar (Xinong 979) was sown at the rate of 2,250,000 seeds ha^{-1}. The seed were planted with an inter-row space of 20 cm during October 15 in 2015 and on October 10 in 2016. Wheat was hand harvested on June 2 in 2016 and on May 27 in 2017. Whole of the nitrogen (urea) and phosphorus (diammonium phosphate) were applied at the time of planting at the rates of 225 and 75 kg ha^{-1}, respectively. The levels of simulated rainfall were determined based on the distribution of rainfall in the semi-arid regions of northern China over the past 48 years.-years period (1966–2014). Three total amounts of simulated rainfall, 125, 200, and 275 mm, corresponding to light (1), moderate (2), and heavy (3) simulated rain levels, were applied as described in a previous study (Liu et al., 2013; Ali et al., 2017). In this study, a precipitation simulator was used to provide the crop water, and no natural rainfall was allowed during wheat growing season. A complete detail of the rainfall conditions can be seen in Table 1. In this rainfall simulator study, the amount of rainwater measured under field conditions was reasonably similar to natural rainfall amounts.

Download English Version:

https://daneshyari.com/en/article/8872894

Download Persian Version:

https://daneshyari.com/article/8872894

Daneshyari.com