Agricultural Water Management 203 (2018) 395–404

Contents lists available at ScienceDirect

Agricultural Water Management

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

Evaluation of net return and grain quality characteristics of wheat for various irrigation strategies under the Mediterranean climatic conditions

Adnan Alghory, Attila Yazar*

Department of Irrigation and Agricultural Structures Science, Faculty of Agriculture, Cukurova University, 01330 Adana, Turkey

ARTICLE INFO

Keywords:
Supplemental irrigation
Deficit irrigation
Line-source sprinkler
Net return
Grain quality
Triticum aestivum

ABSTRACT

This study evaluated the effect of different supplemental and conventional irrigation strategies on economical parameters, yield and grain quality characteristics of wheat (*Triticum aestivum* L., cv. Adana 99) using sprinkler line-source system during 2014 and 2015 seasons in the Mediterranean region. The irrigation strategies were Conventional irrigation (CI), Supplemental irrigation (SI) during flowering (SIF), SI during grain filling (SIG), SI both during flowering and grain filling (SIFG). These strategies were tested under four irrigation levels 100, 75, 50, 25% of crop water requirement, and a rain-fed treatment was included as control.

Conventional full irrigation (CI_{100}) treatment achieved the highest grain yield and maximum net return in both seasons. The higher deficit irrigation treatments resulted in negative net return in dry season but positive in wet season. $SIFG_{100}$ and SIF_{100} generated a net return of 668.53 and 424.22 $/ha, respectively. CI_{75} produced more yield and net income in comparison with $SIFG_{100}$ that although irrigation amount was less but the yield and net income were 26 and 7.65% greater; furthermore CI_{75} saved 23.3% of water with small grain yield reduction of 4.45% as compared to CI_{100}. Therefore CI_{75} can be recommended to maximize yield and net income under scarce water conditions.

In this study, higher water stress occurring in the dry year helped to improve the grain quality and made it richer than wet year. The findings showed positive response between the quality parameters such as protein content, wet gluten content and sedimentation volume, and water stress. $SIFG_{75}$ treatment was the best irrigation strategy for high grain quality parameters (with small yield reduction as compared to CI_{100}). It could be recommended to obtain high yield and good quality indicators under Mediterranean conditions.

1. Introduction

Wheat (*Triticum aestivum* L.) is one of the most important crops, providing over 20% of the calories consumed by the world's population (Braun et al., 2010). In the year 2050, the world population is estimated to be 9 billion, while the demand for wheat is estimated to reach more than 900 million t (Dixon et al., 2009). According to Pala et al. (2011), average yield gaps in Morocco ranged from 98 to 207% in rainfed areas and from 51 to 89% in irrigated areas. Similarly yield gaps of 82–125% and 61–201% have been reported in Syria and Turkey, respectively. In relation to the study years 2014 and 2015, the wheat harvested area in Turkey amounted to 7.7 and 7.9 million ha; it produced 15.3 and 18.5 million t, and consumed 17.5 and 17.8 million t (Grain World Markets and Trade, 2015).

Winter wheat water use (evapotranspiration) depends on cultivar, growth stage, canopy and leaf structure, climatic conditions, irrigation, soil, and crop management practices. The Mediterranean region is characterized by a short rainy season (November–April), increasing water deficit and thermal stress during wheat grain filling stage. Adequate water on or after anthesis period not only allows the plant to increase photosynthesis rate but also gives extra time to translocate the carbohydrate to grains (Zhang and Oweis, 1998) which improve grain size and thereby lead to increase grain yield (Tari, 2016). Padhi et al. (2010) reported that grain yield, straw and leaf area index have significant differences among treatments where the full irrigation treatment resulted in greatest values and these features decreased with increasing stress levels. Rao et al. (2012) found the highest value of the total biomass, grain yield and harvest index of wheat under full irrigation using line source sprinkler irrigation in comparison to deficit irrigation levels. Highest average grain yield of wheat was attained from the highest irrigation level (full irrigation) with a 7 day interval as 8.3 t/ha, and the lowest yield was obtained from rain-fed treatment with 2.9 t/ha in arid Southeast Anatolia region (Sezen and Yazar, 2006). Rajala et al. (2009) stated that drought reduces photosynthesis, plant water content and leaf area development.

Mary et al. (2001) reported that the water stress has played a key

* Corresponding author.
E-mail addresses: yazarat@cu.edu.tr, yazarat@mail.cu.edu.tr (A. Yazar).

https://doi.org/10.1016/j.agwat.2018.03.033
Received 28 September 2017; Received in revised form 21 March 2018; Accepted 23 March 2018
0378-3774/

role to reduce the moisture percentage, while it increased protein and gluten contents. Water stress in the post-anthesis (grain filling period) was found to affect quality parameters where an increase in protein content and sedimentation volume, consistent with a decrease in grain yield, 1000 grains weight, bread volume and wet gluten were observed when a terminal water stress happened (Aslani et al., 2013). Noorka and Silva (2012) found under normal irrigation condition the protein contents of wheat ranged from 11.20 to 13.78% while under water stress condition it ranged from 12.47 to 13.92%. Kiliç and Yağbasanlar (2010) concluded that drought stress increased the chlorophyll content, grain protein content and sedimentation. Tari (2016) found that the water stress applied in the stem elongation stage and irrigation applied in the milk stage increased the protein ratios, while the highest protein ratios and gluten contents were obtained under the moisture conditions of full irrigation at milk stage (14.5%) during the first year, and under the full irrigation at heading and milk stage treatment (14.7%) during the second year in Konya Plain in Turkey. Erekul et al. (2012) stated that sedimentation values and wet gluten contents at different supplemental irrigation doses ranged between 27 and 37 ml and 26.5–34.4%, grain protein content ranged between 11.7–14.9%. Protein contents, sedimentation values and wet gluten contents without irrigation were significantly higher than the values obtained from the supplemental irrigations. On the other hand, Gooding et al. (2003) reported that drought stress before the end of grain filling decreased sedimentation volume relative to drought applied later. Ozturk and Aydin (2004) observed that late water stress increased grain protein, sedimentation volume, and wet gluten content relative to the fully irrigated treatment in a red-grained winter bread variety. Naseri et al. (2010) revealed that water stress increased protein contents by 10.3–13.2% in wheat, while Seleiman et al. (2011) reported that less irrigation and water stress increased protein content by 11.20–13.40% as compared to full irrigation. Saint-Pierre et al. (2008) expressed that with the application of SI the protein content begins to decrease as expected.

Attaining higher yields with increased productivity is only economical when the increased gains in crop yield are not offset by increased costs of other inputs (Oweis and Hachum, 2004). Eid et al. (2014) attained the best results under set sprinkler irrigation system and irrigation frequency three times per week with maximum wheat grain yield (5.8 t/ha) and net income (1289.3 $/ha); on the other hand, hand-move sprinkler system and irrigation frequency once per week achieved the lowest yield (3.3 t/ha) and net income (−199 $/ha) in Egyptian national research centre. Optimum water use in deficit irrigation is obtained by an economic analysis using yield and cost functions. If land is limiting, optimum irrigation strategy would be to apply the amount of water which maximizes net income as described by English and James (1990). Many investigators have concluded that deficit irrigation can increase net farm income (Fardad and Golkar, 2002; Zhang et al., 2002). Ali et al. (2007) found highest net return of wheat under both land and water-limiting conditions using 2 irrigation (130 mm) amounted 87.1 and 154.3 $/ha with yield 3.3 t/ha; however, under 4 irrigations (265 mm) amounted 70.4 $/ha with yield 3.8 t/ha, and the lowest net income was negative (−74.5 $/ha) under the conditions of using 18 mm irrigation water since the cost of production was higher than gross return and yield was 1.8 t/ha. Dağdelen et al. (2009) stated that the reduction in the net income of the deficit irrigation treatments (DI-25 and DI-50) was significant and seemed to be non profitable with negative values (−2672.5 and −877.7 $/ha) in the Aegean region of Turkey.

A few studies examined the appropriate conventional and supplemental irrigation dose and analyzed the economic return to determine the most economic irrigation system alternative. Hence the purpose of this study is to evaluate and compare the economic feasibility of agriculture with conventional and supplemental irrigation strategies in the Mediterranean region in order to maximize the net benefit from optimal wheat production (no maximizing yield) and determine the suitable SI amount especially under limited water and land resources. Additionally, this work was carried out to evaluate the effect of conventional and supplemental irrigation applied at the critical growth stages on grain yield and bread-making properties in order to improve wheat quality, and to study the correlation of different quality parameters and grain yield.

2. Materials and methods

2.1. Experimental site

The experiment was carried out in the Research Field of the Irrigation and Agricultural Structures Department at Çukurova University, (36°59′N Lat., 35°18′E Long. and altitude of 35 m asl) located in Adana, Turkey, during the 2013/2014 and 2014/2015 wheat growing seasons using a local wheat (*Triticum aestivum* L.) cv Adana 99.

2.2. Soil and water features

The soil of the experimental site is classified as the Mutlu soil series (*Palexerollic Chromoxeret*, FAO, 2006), with a clay texture throughout the soil profile, and has a pH range 7.62–7.78, electrical conductivity of the saturation extract (EC_e) 0.12–0.19 dS/m, and volumetric soil water contents at field capacity (FC) and permanent wilting point (WP) of the root-zone 40–41% and 19–24%, respectively. Mean bulk density varies from 1.15 to 1.25 g/cm^3. The available water-holding capacity of the soil is 198 mm in the 120 cm soil profile. Water is obtained from an open channel irrigation system in the experimental area, and the quality is classified as (C_2S_1) by USSL (1954) and pH is 7.8, and the average electrical conductivity is 0.78 dS/m.

2.3. Climate

Çukurova region is placed in a semi-arid climate. Weather data were collected from an automatic recording meteorological station located at the experimental site. Precipitation, maximum and minimum air temperatures, air humidity, wind speed and solar radiation measured on a daily basis, and summarized for each growing season along with climatic data during the long-term of period 1960–2015 are reported in Table 1.

2.4. Experimental design and treatments

In the experiment, line source sprinkler design was employed for studying the effect of supplemental, deficit irrigation strategies and irrigation levels on wheat yield and yield components. Separate sprinkler lines were employed for the main treatments and sprinkler lateral was laid out parallel to plant rows. The line source sprinkler system was used to assess crop yield response to different levels of deficit irrigation, where the applied irrigation water is uniformly distributed parallel to sprinkler lateral and water application gradually decreased with distance away from the line source (Sezen and Yazar, 2006).

In this study, four irrigation strategies were considered, namely CI, and SI at flowering and grain filling (SIFG), only at flowering stage (SIF), and only at grain filling stage (SIG). Four irrigation levels in each irrigation strategy, namely one full (I_{100}) and three deficit (I_{25}, I_{50} and I_{75}) irrigations and a rain-fed (RF) treatment were considered. The experiment was carried out with randomized complete blocks design with four replications using line source sprinkler system for each irrigation strategy.

The amount of irrigation water applied in conventional full irrigation strategy is based on restoring root zone moisture deficit (when 50% of available water is depleted in effective root-zone depth of 90 cm) to near field capacity for the full irrigation treatment next to the sprinkler lateral (I_{100}). The other irrigation treatments automatically received approximately linearly decreasing proportions (0.75, 0.50 and 0.25) of