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Supplemental irrigation effect on canola yield components under semiarid climatic conditions

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ABSTRACT

With the availability of irrigation water, supplemental irrigation in winter-grown crops, such as lentil, wheat, and barley, has been intensely practiced to prevent crop yield losses due to the incidence of intermittent drought stress. In the crop growing seasons of 2006–2007 and 2008–2009, a study was conducted to determine the effect of supplemental irrigations on Canola (*Brassica napus* L. cv. Elvis F1) under the semiarid climatic conditions of the Harran plain, Sanliurfa, Turkey. A sprinkler irrigation system was used to irrigate the study plots. The irrigation treatments included 0.0, 0.25, 0.50, 0.75, and 1.0 (full irrigation) of Class-A pan evaporation amounts. The full irrigation treatment during both years consisted of 250 and 225 mm, respectively. In turn, crop water use values during the same years and treatments were 462 and 449 mm. In general, plant height and 1000 seed weight ranged from 140 to 165 cm and from 2.5 to 3.3 g, respectively, and these variables significantly differed among irrigation treatments ($p < 0.05$). Crop yield and above ground biomass measurements were affected by irrigation treatments and varied from 1094 to 3943 kg ha^{-1} and from 6746 to 18,311 kg ha^{-1}, respectively ($p < 0.05$). Similarly, harvest index values were affected ($p < 0.05$) and ranged from 0.16 to 0.23 on average. The water use efficiency obtained in the different treatments indicated a strong positive relationship between crop yield and irrigation. Overall, our results indicate that supplemental irrigation substantially increased canola yield; however, for an optimum yield, full irrigation is suggested.

1. Introduction

The Harran plain is part of the Fertile Crescent area of the upper Mesopotamia in Turkey. This region was gradually opened to irrigation since 1995 as part of the Southeastern Anatolian Project (locally called GAP), which is a social and agricultural integrated project covering approximately 1.8 million hectares of agricultural land. Even though cotton is the dominant crop grown in the plain, there is a need to diversify crop patterns to ensure sustainable farming practices; hence, alternative crops such as canola could easily fit as a second crop rotation. Although there is enough fresh water for the whole plain, some farms, particularly at the lower areas, suffer from drought mainly due to inefficient irrigation practices in the upper part of the plain. In addition, because of the increased water table, currently covering 35,000 ha of agricultural land at the lower part of the plain (State Hydraulic Works, DSİ, 2004), salinity has gradually increased (Bahceci and Nacar, 2009) and is severely affecting agricultural production. Canola as an oil crop and, due to its tolerance to salty conditions (FAO, 2002), could easily be cultivated in the lower part of the plain as a winter crop.

Due to a low annual oil crop production, Turkey exports 1.72 million ton of oil seeds to meet demand (BSYD, 2011) and, as a result, canola constitutes a critical oil crop for the country. In particular, canola seeds contain approximately 40–45% high quality oil that could not only be used for human consumption but also as biodiesel (Ariolu et al., 2010). Moreover, the remaining seed pulp can be used as animal food. Traditionally, canola is grown under dry conditions; however, with the incentives of governmental subsidies and high prices, it is currently cultivated in irrigated fields as well. In Turkey, canola production increased from 0.028 to 0.112 million kg from 2007 to 2009, respectively (BSYD, 2011), and its cultivated area is expected to expand to the whole country, including the southeast region, because of favorable climatic conditions and availability of water sources.

Drought stress is a key limiting factor leading to lower crop yields, especially in the late growing season of winter crops because there is not enough precipitation during the spring months. Reddi and Reddi (1995) indicated that, in many parts of the world, water

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is the major factor limiting crop production because water shortage affects several plant physiological processes (Sinaki et al., 2007). Therefore, the availability of water improves most crops' yield, including canola yield (Smis et al., 1993). Likewise, most field crops, including canola, are sensitive to water stress during flowering and seed filling stages (Richards and Thurling, 1978; El Hafid et al., 1998; Costa and Shanmugathasan, 2002; Karam et al., 2005; Dogan et al., 2007). Taylor et al. (1991) indicated that, in addition to precipitation, supplemental irrigation increased canola yield and yield components. Similarly, Kar et al. (2007) reported that there was a need for irrigation of safflower in addition to winter and spring precipitations. Most irrigation studies are conducted concomitantly with fertilizer trials (Cheema et al., 2001; Svecnjak and Rengel, 2006); therefore, irrigation studies alone are limited and needed (Abuelos et al., 2002). Abuelos et al. (2002) conducted an irrigation study to determine the effect of water stress on canola and applied irrigation water in varying amounts from 0.0 to 359 mm. As a result, there was a significant difference between yield and yield components of full and insufficiently or no irrigated canola.

Jensen et al. (1996) stated that water deficit during vegetative growth and pod-filling stages decreased the number of seeds, harvest index and yield. Similarly, Sharma and Kumar (1989) and Singh et al. (1991) reported that water stress resulted in lower leaf area index, harvest index, number of leaf and branches and, thereby, in a significant yield loss. Likewise, similar to other field crops, canola response to water stress depends on the growth stage in which the stress occurs; specifically, any stress during and/or prior to flowering resulted in a lower number of pods, 1000-seed weight and reduced yield (Taylor et al., 1991; Mendham and Salsbury, 1995; Angadi et al., 1999; Johnston et al., 2002; Gan et al., 2004). Parallel results were reported by Richards and Thurling (1978); however, they claimed that, even though drought stress resulted in less number of seeds in pods, the 1000-seed weight tended to increase.

Drought stress during vegetative, flowering and seed formation stages in canola resulted in considerably reduced yield (Muhammad et al., 2007). Ahmadi and Bahrani (2009) stated that canola yield was mainly limited by water stress and high temperatures in arid and semiarid regions, especially during crop reproductive stages where a slight water and temperature stress could result in lower yield. Similar to other studies, Ahmadi and Bahrani (2009) reported that water stress during flowering resulted in the highest reduction of canola yield (29.5%).

Mandal et al. (2006) conducted a study to determine the effect of irrigation and nutrients on mustard growth and yield under central India conditions. They applied water at different stages (pre-sowing, post-sowing and flowering) at 60 mm rates. Finally, they reported evapotranspiration (ET) values that varied from 90 to 290 mm. Overall, water stress resulted in reduced root development, biomass, and yield, and irrigation almost doubled the yield.

Many researchers agree that there is a need to determine a proper irrigation schedule, to apply the appropriate amount of water needed by the crop, thereby increasing the water use efficiency (Kipkorir et al., 2002; Kar et al., 2007). Information on the possible effects of irrigation on canola physiological characteristics is limited and needs to be further evaluated under different climatic conditions.

Because of water shortage at the lower part of the Harran Plain, the probable effect of climate change, which might decrease the annual precipitation rate in approximately 20% in the region, and the high frequency of drought stress in the rapid crop growing season, the effect of supplemental irrigation on development and yield components needs to be determined. Therefore, the objectives of this study were (1) to monitor the effects of seasonal supplemental irrigation on canola growth and yield components and (2) to determine water use efficiency and irrigation water use efficiency under the semiarid climatic conditions of the study area.

2. Materials and methods

The experiment was conducted at the Agricultural Engineering Research Field (37°08′N, 38°46′E, with an altitude of 465 m) of the Harran University, Sanliurfa, Turkey. The research station is located in the southeast of Turkey, at 45 km from the Syrian border, and it is characterized by semiarid climatic conditions. The clay loam soil type is classified within the Ikizce soil series (Vertic Calciorthid Aridisol) with a field capacity of 32%, permanent wilting point of 22%, 155 mm/120 cm of available water, and infiltration rate of 13 mm h^{-1} (Table 1). Long term average temperature, relative humidity, and wind speed values of the study area were 18.1 °C, 52%, and 1.7 m s^{-1}, respectively.

A commonly grown canola cultivar, 'Elvis', was used as the plant material for the experiment. The source of irrigation water was a deep well with pH and EC values of 7 and 0.31 dS m^{-1}, respectively. A sprinkler irrigation system with a 12 × 12 arrangement was used to deliver water to treatment plots, and the used sprinkler heads were of impact type with 0.35 l s^{-1} flow rates. Due to the sprinkler irrigation set up, the treatment plots were 144 m^2 in size. There was a 12.0 m buffer zone among plots, to eliminate any effect of one plot on another. In both study years, there was no need for post-sowing irrigation because there was precipitation after planting. In total, there were 3 supplemental irrigation events during the spring months of both study years. The irrigation events were scheduled to apply an amount of water equal to the evaporation obtained from a standard Class-A Pan located close to the study area. Irrigation events were initiated when the soil available water content reached 50%.

Canola seeds were sown by a pneumatic precision planter on November 18th and 15th of 2006 and 2008, respectively. All treatments received 150 kg ha^{-1} of pure N in two equal amounts: one at sowing and the other in the spring of both growing seasons. In addition, 60 kg ha^{-1} of pure P was applied to treatment plots at sowing. Weed control was managed by two hand-hoeing events, and herbicide and pesticide were not applied in either year.

In this study, irrigation amounts were determined with the following equation,

$$I = \mathrm{Epan} \times \mathrm{Kp} \times \mathrm{CP} \times A \quad (1)$$

where I is the applied irrigation water (mm), Epan is the cumulative evaporation amount in the irrigation interval (mm), Kp is a pan coefficient, CP is the crop soil coverage (%), and A is the area (m^2).

Crop evapotranspiration (ETc) during the irrigation period of each treatment was calculated according to the water balance approach (Doorenbos and Pruitt, 1992),

$$\mathrm{ET} = I + P - \mathrm{Dr} - \mathrm{Rf} \pm \Delta s \quad (2)$$

where ET is the canola crop evapotranspiration (mm), I is the irrigation water applied during the growth period (mm), P is the effective rainfall plus capillary rise (mm), Dr is the drainage water amount (mm), Rf is the runoff amount (mm), and Δs is the change in soil moisture content (mm) determined by gravimetric sampling. During the irrigation periods of both study years, there was no precipitation, excess irrigation and runoff; therefore, P, Rf and Dr were assumed to be zero, reducing the equation to

$$\mathrm{ET} = I \pm \Delta s \quad (3)$$

The treatments used in this study included 0, 25, 50, 75, and 100% of full (control) irrigation amounts. Once plants reached maturity, 2 m × 3 m (6 m^2) sections from all plots were hand harvested, and plant height, 1000-seed weight, crop yield, and biomass values