academicJournals

Vol. 12(13), pp. 1158-1163, 30 March, 2017
DOI: 10.5897/AJAR2016.12011
Article Number: AC4B20563481
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Behavior and water needs of sesame under different irrigation regimes: III. Production and hydric efficiency

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Received 28 November, 2016; Accepted 13 March, 2017

This study aimed to identify the irrigation depth (305, 436, 567 and 698 mm), applied on the basis of crop evapotranspiration- ETc (the depth of 567 mm was equal to 100% of ETc) for best yield (Y) and water use efficiency (WUE) for irrigation and soil water stress tolerance (Ky) of sesame BRS 196 CNPA G4. The experiment was conducted at Embrapa Cotton, Barbalha County, CE State, Brazil, in 2012. The experimental design was randomized block, with three replications. ETc was calculated by multiplying the reference evapotranspiration (ETo) determined by Penman-Monteith method with the crop coefficients (Kc) recommended by FAO. For other irrigation treatments, ETc was multiplied by 0.4, 0.7 and 1.3 (40, 70 and 130% of ETc). During harvest, number of capsules (NC) per plant, yield (Y), oil content (O) of seeds, WUE and Ky were counted, calculated and determined. It was concluded that 698 mm irrigation depth provided the highest yield and oil content of sesame seeds; 305 mm irrigation depth allowed the best WUE of sesame irrigation; and, sesame BRS 196 CNPA G4 plants were tolerant to soil water stress.

Key words: *Sesamum indicum* L., evapotranspiration, fruits number, oil content, water stress.

INTRODUCTION

The low yield of sesame (*Sesamum indicum* L.) in semi-arid areas is mainly from low use of inputs, inadequate management and occurrence of abiotic stresses (Pham et al., 2010). For example, in the Northern part of Brazilian semiarid regions, irregular and scarce rainfall is marked by the concentration of it for three or four months

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per year (Farias et al., 2000).

Sesame crop has good yield even in those conditions. So it is believed that with irrigation, it is possible to get a significant increase in its yield (Uçan et al., 2007). Therefore, it is urgent to conduct researches on its water consumption to obtain full development of its crop and best water use efficiency (WUE).

Thus, to achieve maximum yield and income profit per hectare, the available water should be used efficiently (Uçan et al., 2007). Traditionally, agricultural research has focused primarily on maximizing total production. In recent years, the focus has been shifted to the factors limiting production systems, including the availability of land or water (Geerts and Raes, 2009).

The response factor of crops to drought (Ky) is a dimensionless parameter that relates the relative decrease in yield of any crop (herbaceous or woody) with relative decrease of irrigation. That factor indicates the tolerance of a particular crop to water stress, being specific to any culture and conditions (Allen et al., 2012).

This study aimed to identify the effect of irrigation depth (s) on the yield (Y), water use efficiency (WUE) for irrigation and water stress tolerance (Ky) of sesame BRS 196 CNPA G4.

MATERIALS AND METHODS

The study was carried out at the Experimental Field of Embrapa Cotton, located in Barbalha County, CE State, Brazil. Its geographical coordinates are: 07°19'S, 39°18' W and 409 m relative to the mean level of the sea (Ramos et al., 2009). It was conducted from August 4^{th} to November 7^{th}, 2012, in an area of Fluvic Neosoil.

The experiment was installed in randomized blocks, with four treatments (T_1, 305; T_2, 436; T_3, 567 and T_4, 698 mm) of total net depth of water applied in the cycle, corresponding to the treatment T3 to 100% of crop evapotranspiration- ETc), distributed in plots with three replications. The chemical characterization (0 to 20 cm) of the soil carried out at the Soil Laboratory of Embrapa Cotton, Campina Grande County, PB State, Brazil, was as follows: pH 6.8; 95.3; 49.2; 2.8; 1.4 and 0.0 $mmol_c\ dm^{-3}$ of Ca, Mg, Na, K and Al, respectively; 5.4 mg dm^{-3} of P and 12.3 g kg^{-1} of organic matter.

The soil was prepared by plowing with chisel. Fertilization (123-152-30 kg ha^{-1}) was performed according to the chemical soil analysis and technical advice from Embrapa Cotton. Sowing was done on August 8^{th} 2012 using five seeds of sesame BRS 196 CNPA G4, at 0.20 m row, and spacing of 0.70 m between rows.

The irrigations were performed using conventional spray, with efficiency of 75% and 0.34 MPa working pressure; spray nozzles of 5.0 x 4.6 mm and rainfall of 10.54 mm h^{-1} were used. The space was 18 x 12 m with water applied from the ground, which, according to Amaral and Silva (2008), matches the profile of the soil explored by the roots of sesame. They were every 3 or 4 days due to clayey texture of the soil of the area to promote a very low water infiltration into the soil. From the beginning of the maturation stage (67 DAE), irrigations were done weekly, considering the smaller replacement required by the irrigation crop. In every irrigation, the net depth (ND) of replacement (ND = ETc = ET_0 x Kc) was function of the ET_0 of the period, estimated by Penman-Monteith method using weather data from INMET Weather Station in Barbalha, CE State, Brazil, 500 m far from the experimental area and, the crop coefficients (Kc), contained in FAO 56 (Allen et al., 2006).

The average Kc used was as follows (Allen et al., 2006): Phase I-Establishment (2 to 5 DAE): 0.63 (Kc-initial); Phase II- Growth (6-32 DAE): 0.79 (Kc-intermediate); Phase III- Floration (33-66 DAE): 1.10 (Kc-medium) and; Phase IV- maturation (67-90 DAE): 0.25 (Kc-final). Differentiation of irrigation treatments started at 13 DAE. From then up to the last irrigation, on the other treatments, the replacement net depth (ND) calculated for the treatment based on 100% of ETc was multiplied by 0.4, 0.7 and 1.3 with the replenishment volumes of irrigation treatments with 40, 70 and 130% of the ETc.

During harvest (90 DAE), per experimental unit, the number of capsules (NC) or fruits per plant was counted; the yield of seeds (Y - kg ha^{-1}) was determined, seeds were weighed and 0.5 kg of seeds was collected for determining the oil content (O -%) at Soil and Plants Nutrition Laboratory of Embrapa Cotton, in Campina Grande, PB.

The water use efficiency (WUE - kg m^{-3}) was determined, according to Allen et al. (2006), by the relation between the sesame seeds yield (Y - kg ha^{-1}) and the volume of water (V - m^3 ha^{-1}) applied to each irrigation treatment given to the crop, according to Equation 1:

$$WUE = Y/V \quad (1)$$

The response factor to water stress (Ky) was estimated according to FAO-56 (Allen et al., 2006), by the ratio between the relative decrease of yield (RDY) (1 – Ya / Ym) and the relative decrease of irrigation (RDI) (1 – ETc / ETm), according to the Equation 2:

$$Ky = [(1 - Ya / Ym)] / [(1 - ETa / ETm)] \quad (2)$$

Where, K_y is the response factor to water stress, defined as a decrease in yield (RDY) related to the decrease in the applied irrigation depth (RDI - dimensionless); Ya is the yield in a given applied irrigation depth (kg ha^{-1}); Ym is the maximum yield (kg ha^{-1}); Ya/Ym is the relative yield (dimensionless); (1 – Ya/Ym) is the decrease in the relative yield (RDY - dimensionless); ETa (Actual Crop Evapotranspiration) or ETc is the applied irrigation depth that results in the yield Y_a (mm); ETm is the maximum depth of applied irrigation (mm); Eta/ETm is the relative irrigation depth (dimensionless); (1 – ETa/ETm) is the relative decrease in the applied irrigation depth (RDI - dimensionless).

The response factor to water deficit (Ky) was not statistically analyzed because it is native from method and specific equation. The variables related to the components of production (number of capsules per plant, yield and seed oil content) and water use efficiency (WUE) were subjected to analysis of variance by the tests F and polynomial regression, both 1 and 5% of probability using the statistical software Sisvar (Ferreira, 2011).

RESULTS AND DISCUSSION

By analysis of variance and regression, the irrigation depths differed from each other on yield (Y), oil content (O) and water use efficiency (WUE); they adjusted themselves to the polynomial linear regression. However, the number of capsules (NC) per plant was not affected by the applied depths or adjusted itself to the adopted regression model (Table 1).

In this study, there was no evidence of the influence of irrigation depths on the NC of the sesame. On the contrary, Kassab et al. (2005), in the African semi-arid, comparing systems and irrigation depths in sesame Giza

Table 1. Summary of variance analysis of the number of capsules (NC), yield (Y), oil content (O) and water use efficiency (WUE) of sesame in the applied irrigation depths. Barbalha, CE State. 2012.

Variation source	**DF**	**NC**	**Y (kg ha^{-1})**	**O (%)**	**WUE (kg m^{-3})**
		Mean square			
Blocks	2	1.20ns	167592.09ns	0.66ns	0.005ns
Irrigation depths	3	4.41ns	281762.84*	27.72**	0.007*
Linear	1	5.29ns	765733.25**	80.04**	0.012*
Quadratic	1	3.02ns	49758.01ns	1.14ns	0.006ns
Cubic	1	4.91ns	29797.27ns	1.98ns	0.002ns
Deviations	1	0.00**	0.00**	0.00**	0.000**
Error	6	2.00	63500.90	0.79	0.001
CV (%)	-	10.36	19.58	1.79	14.74
MEAN	-	188.16	1286.82	49.79	0.27

*Significant ($p < 0.05$), ** significant ($p < 0.01$), ^{ns}not significant ($p > 0.05$), CV is the statistical coefficient of variation.

32 and Mesquita et al. (2013), evaluating drip irrigation in BRS Seda, in Fortaleza, CE State, noticed that the NC increased proportionally to the applied depths.

The yield (Y) of sesame seeds BRS 196 CNPA G4 increased proportionally with irrigation (Figure 1). These results corroborate Ahmed and Mahmoud (2010), with sesame Khidir and Promo for two successive harvests (2001/02 - 2002/03) in Sudan, African semi-arid and Silva (2012) in Barbalha, CE State, studying irrigation depths based on ETc. Of the authors cited above, the first produced cultivars of cycle similar to CNPA G4 above 3000 kg ha^{-1}, while the other, with the same cultivar, irrigation system and locality of this study obtained 1500 kg ha^{-1}, but he also did not reach the varietal potential of sesame BRS 196 CNPA G4- 2000 kg ha^{-1}, according to Arriel et al. (2009).

Lima et al. (2011), using sprinkler irrigation in Barbalha, CE State, with the lineage of sesame LSGI-5, produced between 1,300 and 2,929 kg ha^{-1}, but adopting closer spacing than the one mentioned in this experiment; and Grilo Junior and Azevedo (2013), with sesame BRS Seda, in Rio Grande do Norte State, obtained 1,600 kg ha^{-1}, similar to the performance of sesame mentioned in this study.

In smaller applied depths, sesame was very sensitive to water stress condition (Figure 1), causing the decrease in yield, corroborating Uçan et al. (2007). That lower yield is probably due to stomata closure, mechanism of the plants to protect themselves from transpiration, but that reduces photosynthesis and, its growth and development (Taiz and Zeiger, 2009). The oil content in the seeds of sesame BRS 196 CNPA G4 increased proportionally to irrigation, equaling the varietal potential range, which, according to Bezerra et al. (2010) is 50% of oil in the seed, from the irrigation depth estimated in 452 mm (Figure 2).

The results corroborate Kassab et al. (2005) and Silva (2012) who claimed that the oil content of oilseeds increased according to the irrigation. It is similar to the potential (50% of oil) under Brazilian conditions reported by Bezerra et al. (2010), Silva (2012) and Mesquita et al. (2013). On the other hand, as compared to Kassab et al. (2005) and Elleuch et al. (2007), it is evident that in climates similar to Brazilian semiarid, the average of oil content found in sesame exceeds 53%, maximum obtained in this research.

In general, it is observed, corroborating Taiz and Zeiger (2009), that the sesame BRS 196 CNPA G4 had the lowest yield and oil content in seeds in treatments with smaller applied irrigation depths (305 and 436 mm), a fact directly related to drought conditions experienced by plants.

Water use efficiency (WUE) decreased with increased irrigation, resulting in higher efficiency (0.34 kg m^{-3}) with the lower applied depth (305 mm) (Figure 3) because in the water stress level that occurred, a decrease in transpiration (lower leaf expansion, stomata closure) was noticed, but not in photosynthesis (leaf is rarely responsive to moderate water stress), as claimed by Taiz and Zeiger (2009).

In other depths, an average of 0.24 kg m^{-3} (Figure 3) was obtained. Thus, according to Uçan et al. (2007), for better WUE with limited water, sesame shows that, by their morphophysiological conditioning, it uses water efficiently. Conversely, Kassab et al. (2005) and Ahmed and Mahmoud (2010), in the African semiarid observed that WUE increased with the increasing volume of applied irrigation. The response factor to water stress factor (Ky) in all depths was equal to 0.77 (Figure 4), meaning that there is a reduction of 0.77 unit in yield for each decrease of unit in the applied depth, confirming claims of Uçan et al. (2007) that, throughout the cycle,

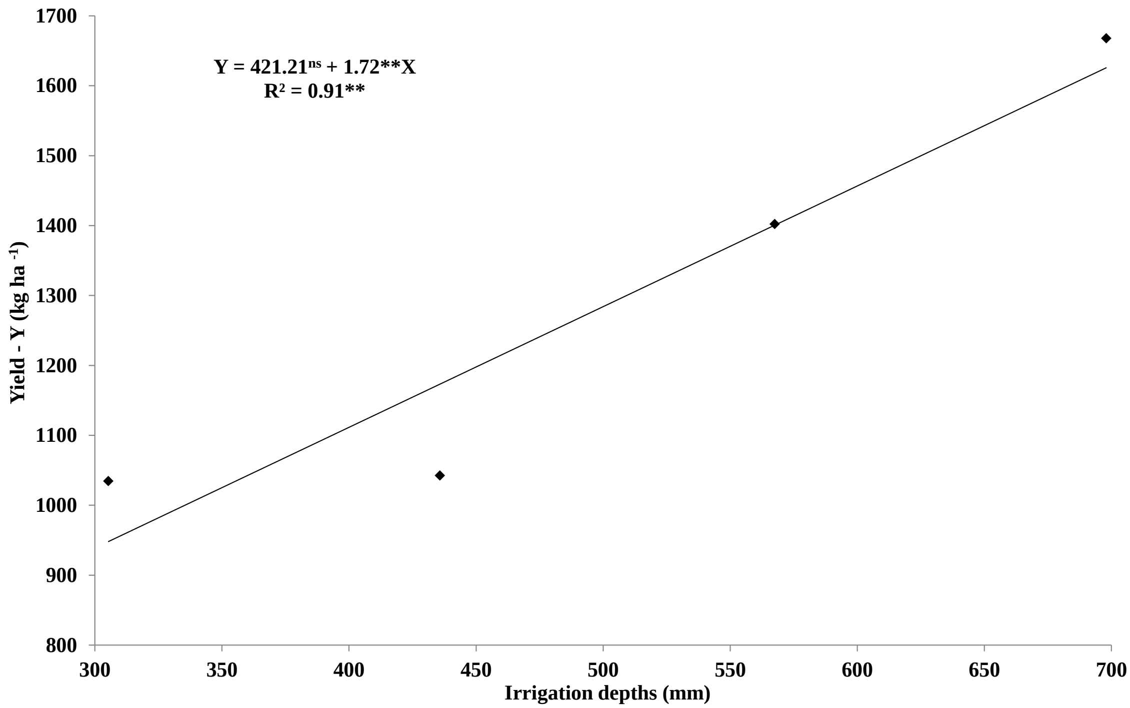

Figure 1. Yield of sesame seeds in the applied irrigation depths. Barbalha, CE State. 2012

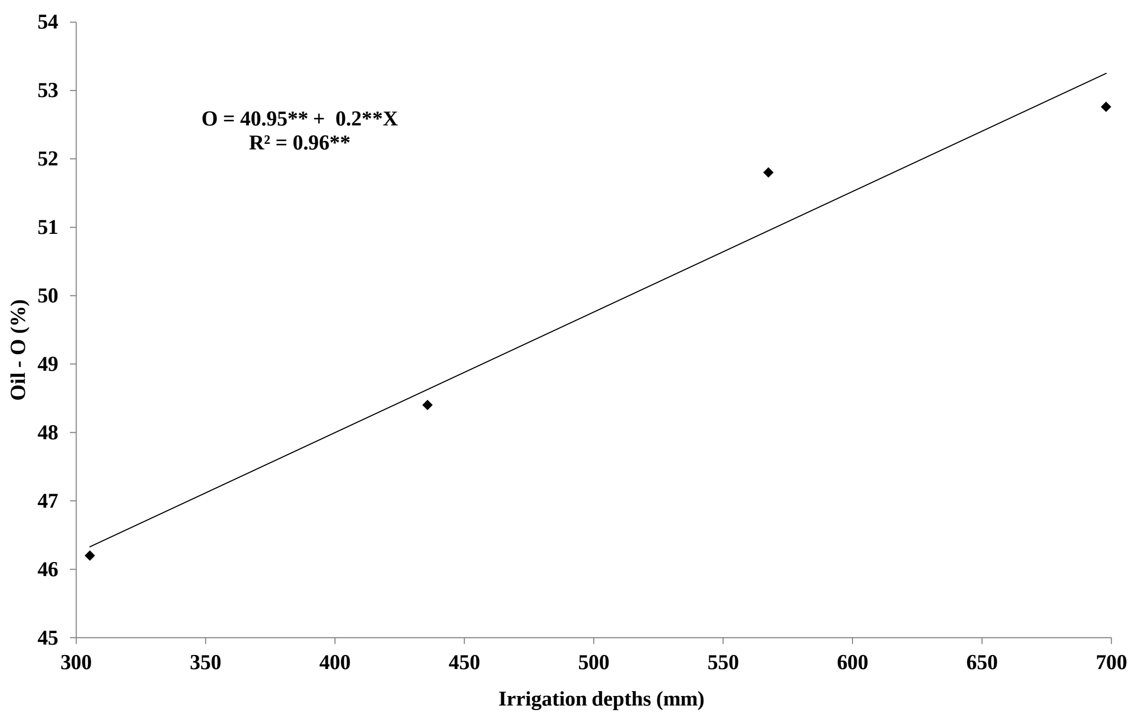

Figure 2. Oil content of sesame seeds in the applied irrigation depths. Barbalha, CE State. 2012

sesame plants were quite tolerant to the lack of water in the soil.

It is observed that the obtained Ky value was less than 1.00 (Figure 4), indicating, according to Allen et al. (2012), that sesame is tolerant to water stress, also agreeing with statements of Bezerra et al. (2010) that the

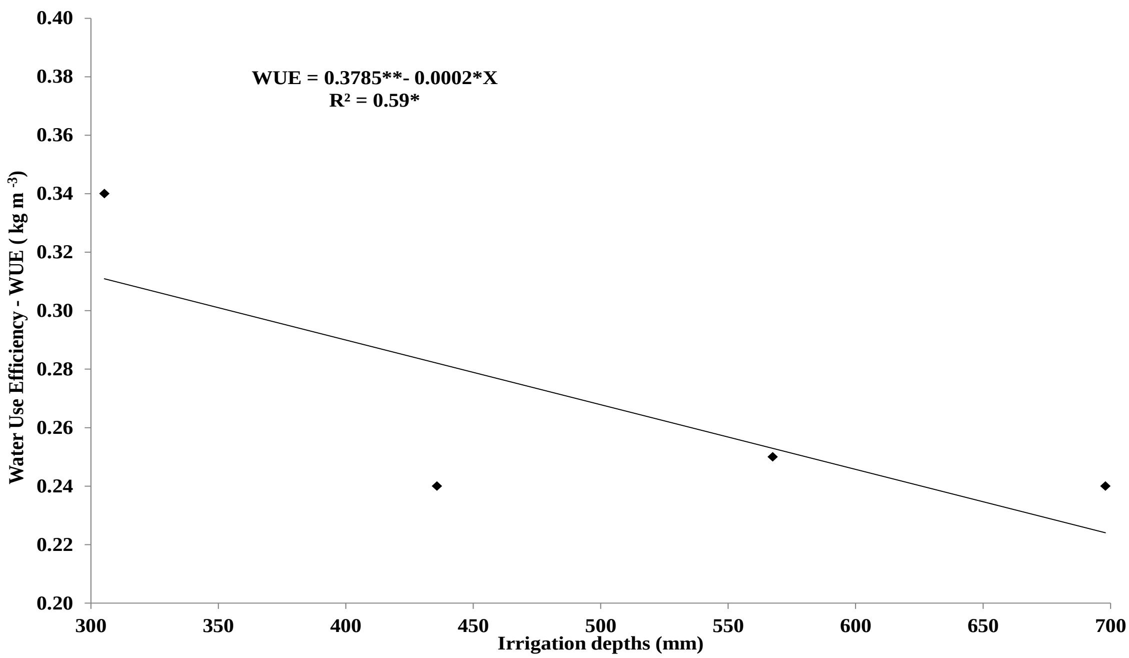

Figure 3. Water use efficiency of sesame in the applied irrigation depths. Barbalha, CE State. 2012.

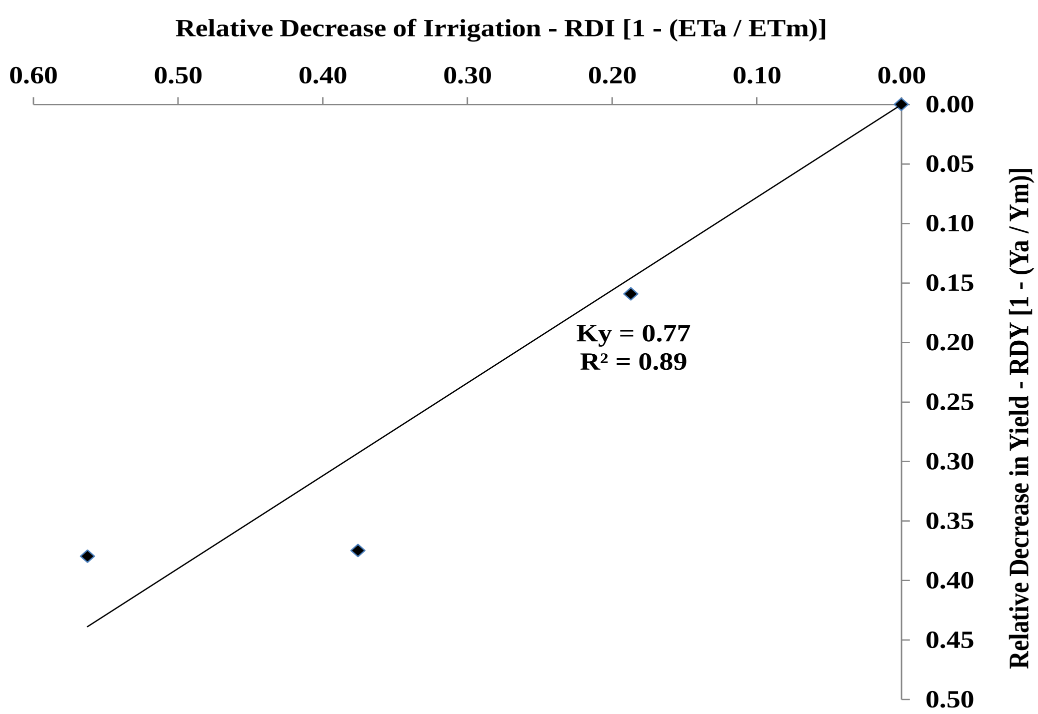

Figure 4. Response factor to water stress factor during the sesame cycle in the applied irrigation depths. Barbalha, CE State. 2012.

plant has a quite high stomata resistance, mechanism used to reduce evapotranspiration and save water for more critical periods in the future of its cycle.

Conclusions

1) The irrigation depth of 698 mm irrigation depth

provided the highest yield and oil content of sesame seeds.
2) 305 mm irrigation depth allowed the best WUE of sesame irrigation
3) Sesame BRS 196 CNPA G4 plants were tolerant to soil water stress.

CONFLICT OF INTERESTS

The authors did not declare any conflict of interest.

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