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Effect of irrigation frequency and amount on water use efficiency and yield of sesame (*Sesamum indicum* L.) under field conditions

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Abstract

The water-use characteristics of sesame (*Sesamum indicum* L.) were studied in the field under furrow irrigation. Irrigation water quantities were based on pan evaporation (E_{pan}) from a screened class-A pan. Treatments consisted of three irrigation intervals (I_1: 7 days; I_2: 14 days, I_3: 21 days), and four pan coefficients ($K_{cp\ 1}$: 0.60; $K_{cp\ 2}$: 0.80, $K_{cp\ 3}$: 1.00 and $K_{cp\ 4}$: 1.20). Average irrigation values for each treatment varied from 467 to 857 mm in 2003 and 398 to 654 mm in 2004. The highest seasonal evapotranspiration was obtained from the $I_3K_{cp\ 4}$ treatment in 2004 (1019 mm); the lowest value was observed in the $I_1K_{cp\ 1}$ treatment in the same year (598.0 mm). Data collected in 2003 and 2004 showed that the amount of irrigation water applied significantly the affected seed yield. However, the effects of irrigation interval on yield were not significant. On average, the $K_{cp\ 3}$ treatment gave the highest seed yield (1.915 t ha^{-1}), whereas $K_{cp\ 1}$ treatment gave the lowest (1.538 t ha^{-1}). Seasonal yield response factors (k_y) were 1.01 and 0.54 in 2003 and 2004, respectively. ET/E_{pan} ratios for each treatment varied from 0.3 to 1.3 in 2003 and from 0.1 to 1.1 in 2004. In conclusion, the $K_{cp\ 3}$ plant-pan coefficient is recommended for sesame grown under field conditions in order to maximise yield.

Keywords: Irrigation; Sesame; Pan evaporation; Irrigation scheduling

1. Introduction

Restricted water resources are a limiting factor for irrigation applications throughout the world. In some locations, naturally available water supplies do not allow the production of maximum yield from irrigable lands. In other regions, water for irrigation is regulated leading to insufficient irrigation. For many surface water projects, the annual supply of irrigation water is limited by reservoir capacity and annual reservoir inflow. These examples highlight the need for deficit irrigation management for different crops (Martin et al., 1989).

It is necessary to produce the maximum yield and profit from per unit area by using available water efficiently because the existing agricultural land and irrigation water are rapidly diminishing due to swift industrialization and urban development. Therefore, it is important to determine the right amounts of water supplies needed for plants during the vegetation period. Furthermore, it is essential to develop the most suitable irrigation schedule to produce the optimum plant yield. Such schedule should be developed for different ecological regions, as plant water consumption during the vegetation period depends mostly on plant growth, soil and climatic conditions.

Yield increase in intensive farming practices mostly depends on timely and adequate application of irrigation water needed for plant growth. Therefore, in addition to a correct determination of plant water consumption and irrigation interval, it is vital to determine the growth period when plants are most susceptible to water deficit in order to generate the highest yield per unit area.

In scheduling irrigation programs, methods based on pan evaporation have widespread usage due to their simple and easy application and low cost (Stanhill, 2002). The pan evaporation method (class-A pan) can be utilized in irrigation programming, if pan coefficients are available. Because evapotranspiration of grown plants can be deduced by pan evaporation using predetermined pan coefficients (Doorenbos and Pruitt, 1977). Studies have shown that there is a close relationship between plant water consumption and pan evaporation that can be used in irrigation scheduling for farmers (Kanber, 1984). Moreover, class-A pan is commonly used in agriculture due to the fact that

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it is the most suitable system for determining relationships among plant, water, and climate.

There are three steps in calculating the plant water consumption and evaporation ratio: (a) deciding on the most suitable irrigation method; (b) choosing the most suitable ET/ET_0 ratio; (c) checking this ratio in the field trials (Goldberg et al., 1976).

Sesame is usually planted in arid and semi-arid regions of the world and should be considered while planning crop irrigation projects in those regions. The plant is very responsive to environmental conditions and abiotic factors such as temperature, humidity, precipitation and soil moisture, all of which can affect its yield and quality. Understanding the relationship between the plant and water consumption as well as developing different management systems based on this knowledge may help maximise the yield. Since water requirements of sesame crops have not been investigated sufficiently so far, irrigation water planning and management need to be studied.

The objective of this study, therefore, was to determine the response of sesame plant to different irrigation applications. Specifically, the effects of irrigation intervals and pan coefficients (K_{cp}) on the yield and water consumption of sesame plants were studied to choose the most appropriate irrigation schedule for plants grown under field conditions using pan evaporation and related plant–pan coefficients.

2. Materials and methods

The study was carried out over the span of 2 years (2003 and 2004) at the Agricultural Research Institute of the Ministry of Agriculture and Rural Affairs in Kahramanmaras, Turkey (37°32′08″N and 36°54′59″E; altitude 568 m a.s.l.). The experimental site lies within an area of 20,000 ha with intensive cropping supported by irrigation. The area has a typical Mediterranean climate—cool and rainy in winter, hot and dry in summer. Table 1 summarizes the monthly maximum, minimum, and average temperatures, relative humidity and precipitation data for the city of Kahramanmaras, in 2003–2004. The average annual temperature, total rainfall, and the relative humidity were about 16 °C, 857 mm, 63% in 2003, and 17 °C, 721 mm, and 60% in 2004, respectively (Table 1). Only 10% of the rainfall fell in the growing season each year. Plants, therefore, required irrigation during the summer season to avoid drought stress.

The soil was classified as an Entisol type with a clay loam texture. The landscape of the site was flat. Soil properties were determined in the laboratory before the experiment (Table 2) Note that the field capacity and wilting point measurements refer to the water contents of soil at 0.33 and 15 atm of moisture tension, respectively.

Experimental plots consisted of 4 rows each 4.0 m long with a 0.7 m row spacing in between (Caliskan et al., 2004). The plots were planted using a 4-row planting machine at a 3-cm depth on 7 May 2003 and 14 May 2004. The plots contained 80 plants in an areas of 11.2 m^2. The distance between each of the plots was 2 m. The cultivar Muganli-57 was selected as the plant material. The reason for choosing this variety relates to the high seed and oil yield of the cultivar and its commonplace use as a registered sesame breed in the region. It is branched and has one capsule per leaf axil (Çağırgan, 1996). Plants were thinned to 20 cm in rows on 18 June 2003 and 24 June 2004. Water was applied equally to all irrigation treatments through sprinklers to increase the soil moisture up to the field capacity (FC) before thinning. Then the process of the irrigation treatment was started (Table 3). A total of 148 mm of water was applied in both years. The numbers of irrigations applied to each of the three irrigation intervals of I_1, I_2 and I_3 were 8, 7 and 4 in 2003, and 7, 4 and 3 in 2004, respectively. Water (2 l s^{-1}) was applied to each furrow in each plot uniformly using a flow meter. The treatment program was stopped at the end of August during both years.

The water used for irrigation was obtained from a deep well in the experimental area. Water quality was classified as C_2S_1, with a pH value of 7.0 and an average electrical conductivity score of 0.33 dS m^{-1}.

All plots were fertilized with the same amount of fertilizer based on soil analysis. The fertilizer contained 75 kg of N ha^{-1}, 75 kg of P_2O_5 ha^{-1}, and 75 kg of K_2O ha^{-1} before planting an additional 75 kg of N ha^{-1} nitrogen at the beginning of flowering. Weeds were controlled manually and hoed as necessary.

The experiment was conducted in three irrigation intervals (I_1: 7, I_2: 14 and I_3: 21 days) and the results yielded four different plant-pan coefficients ($K_{cp\ 1}$: 0.60; $K_{cp\ 2}$: 0.80, $K_{cp\ 3}$:

Table 1
Monthly maximum, minimum, and average temperature, relative humidity and precipitation at Kahramanmaras, Turkey in 2003 and 2004

Month	2003					2004				
	Average temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Precipitation (mm)	Average temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Precipitation (mm)
May	14.1	29.5	15.4	51.9	30.4	20.0	26.4	14.6	62.0	28.7
June	25.6	33.1	18.9	54.0	1.6	25.8	32.5	19.6	56.8	0.0
July	28.3	36.1	22.3	58.2	0.0	29.3	37.2	22.3	53.1	0.4
August	29.4	38.0	22.4	56.6	0.0	28.0	35.6	22.3	58.3	0.2
September	24.3	31.5	17.9	54.7	22.4	26.3	34.8	18.4	45.4	0.0
Annual	16.2			63.0	857.5[a]	17.2			59.7	721.5[a]

[a] Total precipitation.