

Estimation of Evapotranspiration and Water-use Efficiency of Sesame Crop (*Sesamum indicum* L.)

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Abstract: The evapotranspiration rates of sesame crop (*Sesamum indicum* L. cv. RT-127) were quantified using gravimetric lysimeters at Jodhpur during 2009 and 2010 kharif season, maintaining the crop at two levels of irrigation (100% and 50% evapotranspiration, ET) and under rainfed condition. The mean evapotranspiration rates of sesame (100% ET rate irrigated) were 2.5-3.9 mm day⁻¹ during early growth, 6.9-13.5 mm day⁻¹ at vegetative stage, 9.2-9.7 mm day⁻¹ at flowering stage and 5.5-8.5 mm day⁻¹ at seed setting stage. The crop coefficients were 0.3-0.7 at early growth stage, 0.8-1.5 at vegetative stage, 1.6-1.9 at flowering stage and 0.3-1.2 at seed setting stage with an average value of 0.9 for the season. The mean seasonal evapotranspiration, seed yield and water-use efficiency of sesame were 581 mm, 1479 kg ha⁻¹ and 2.54 kg ha⁻¹ mm⁻¹ for 100%ET irrigated crop, 495 mm, 997 kg ha⁻¹ and 2.12 kg ha⁻¹ mm⁻¹ for 50%ET irrigated crop and 362 mm, 635 kg ha⁻¹ and 1.76 kg ha⁻¹ mm⁻¹ for rainfed crop. Relationships between leaf appearance and branch initiation with growing degree days and advection at vegetative stage of crop were also quantified.

Key words: Sesame, arid region, evapotranspiration rates, crop coefficients, water-use efficiency, growing degree days.

India is the largest producer of sesame in the world, accounting for 24% of the world production. Sesame is basically a crop of the warmer climate, though its cultivation extends also to cooler climate. The plant growth and yield are optimum at a temperature range of 24-32°C. Higher temperature than this at flowering and fruit setting results in forced maturity. Seed yield of different cultivars were significantly influenced by row spacing for moisture competition and the highest seed yield was obtained at 30 cm spacing (Nandita Roy *et al.*, 2009). The development of number of capsules, branches and seed yield per plant for each of the genotype was significantly influenced by environmental fluctuations (Tembharne *et al.*, 2007) and also dates of sowing and harvesting (Sarkar *et al.*, 2007). Sesame is basically a short-day plant and with a 10-hour day⁻¹ will normally flower in 40 to 45 days (Mohanty, 1968).

Materials and Methods

The lysimetric study on sesame (*Sesamum indicum* L. cv. RT-127) was conducted at Central Arid Zone Research Institute, Jodhpur (26°18'N, 73°01' E and 223 m above MSL), in an

arid region of north-west India during kharif seasons 2009 and 2010. The weather data were recorded at agro-meteorological observatory located close to the crop field. The crop was sown after onset of monsoon in lysimeters as well as in surrounding field (in about 0.33 ha area) after receiving a good shower of south-west monsoon rainfall. After emergence, the crop was maintained under three irrigation treatments, namely (a) irrigated daily with an amount equal to 100% of evapotranspiration (ET) of the previous day, (b) irrigated every fourth day with an amount equal to 50% of ET of the previous 4 days, and (c) control plots with rainfed conditions. Each of these three lysimeters was surrounded by 5 x 5 m field plots which was maintained with irrigation at the same level as in the lysimeters from which crop-phenology and biomass were recorded. From the daily data, weekly totals/means of these parameters from the date of emergence to maturity were computed. The ET was measured using three gravimetric lysimeters. The reference/potential ET was determined from class A pan evaporation, after multiplying with a pan coefficient (Allen *et al.*, 1998; FAO, 1977). The pan coefficients for kharif season at Jodhpur region were between 0.75 and 0.85, the values were based on FAO (1977) guidelines

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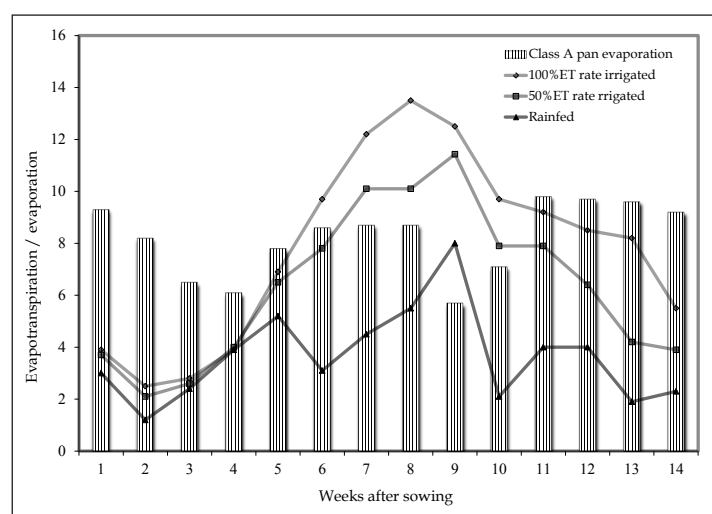


Fig. 1. Reference and actual evapotranspiration rates of sesame at Jodhpur.

as well as pan coefficients determined comparing with potential evapotranspiration using Penman-Monteith formula. The growing degree days ($^{\circ}\text{Cd}$) were computed with 8°C as a threshold temperature following procedure given by Nuttonson (1955) and Sastry *et al.* (1985). Water use efficiency (WUE) was computed as a ratio of seed yield (kg ha^{-1}) to crop evapotranspiration (mm).

Results and Discussion

The mean ET rates of sesame grown under unstressed condition (100% ET rate of irrigation) measured using gravimetric lysimeters during 2009 and 2010 were $2.5\text{--}3.9 \text{ mm day}^{-1}$ at initial stage, $6.9\text{--}13.5 \text{ mm day}^{-1}$ at vegetative stage, $9.2\text{--}9.7 \text{ mm day}^{-1}$ at flowering/seed setting stage and $5.5\text{--}8.5 \text{ mm day}^{-1}$ at maturity (Fig. 1).

The seasonal ET of sesame from transplanting to maturity was 581 mm for unstressed crop with an average seed yield of 1479 kg ha^{-1} and WUE of $2.54 \text{ kg ha}^{-1} \text{ mm}^{-1}$. For 50%ET rate

irrigated sesame, the seasonal ET was 495 mm with a seed yield of 997 kg ha^{-1} and a WUE of 2.12 . For rainfed crop, the seasonal ET was 362 mm , seed yield 635 kg ha^{-1} resulting in a WUE of $1.76 \text{ kg ha}^{-1} \text{ mm}^{-1}$ (Table 1).

Table 1. Seed yield, seasonal evapotranspiration rates and water-use efficiency of sesame at Jodhpur

	Seed yield (kg ha^{-1})		Seasonal ET (mm)		WUE ($\text{kg ha}^{-1} \text{ mm}^{-1}$)	
	2009	2010	2009	2010	2009	2010
100% ET rate irrigated crop	1953	1005	763	398	2.56	2.52
50% ET rate irrigated crop	1018	976	609	380	1.67	2.57
Rainfed	323	947	364	360	0.89	2.63

The crop coefficients (ratio of actual ET to reference ET) for sesame were $0.3\text{--}0.7$ at initial stage, $0.8\text{--}1.4$ at vegetative stage, $1.5\text{--}1.9$ at flowering/seed setting stage and $0.3\text{--}1.2$ at maturity stage with a mean of 0.9 for the cropping season (Fig. 2).

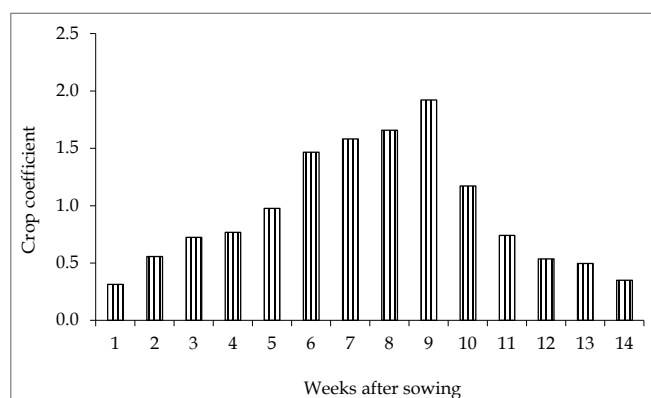


Fig. 2. Crop coefficients for sesame at Jodhpur.

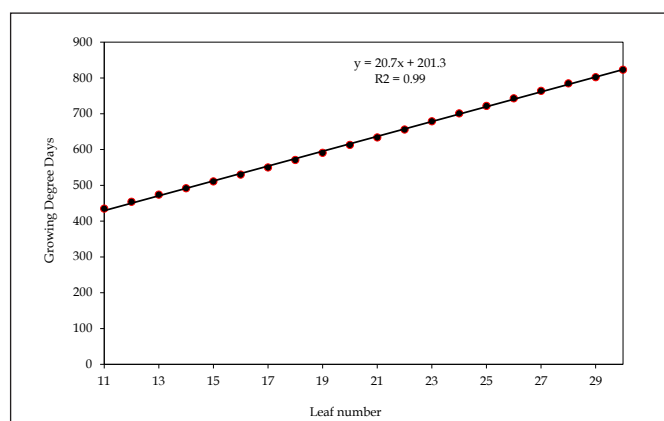


Fig. 3. Growing degree days vs. leaf initiation in sesame.

Under unstressed conditions, the leaf initiation from the main-stem followed a linear trend (Fig. 3) with growing degree days (GDD). It took 435 GDD to initiate first 10 leaves, whereas next 20 leaves took 388 GDD for initiation.

The trend for branch appearance from main-stem was similar to that of leaf initiation under unstressed sesame crop (Fig. 4). The appearance of first branch coincided with the initiation of 11th leaf which had taken 425 GDD. The last 8th branch was initiated at 570 GDD.

Solar radiation during the period varied between 826 to 1375 W m⁻² (Table 2). The net radiation was 506-739 W m⁻² over 100%ET rate irrigated crop, 584 to 810 over 50% ET rate irrigated crop and 556 to 732 W m⁻² over rainfed crop. Albedo which represents the reflected radiation by way of crop and soil moisture conditions was 18-25% over 100%ET rate irrigated crop, 17-23% over 50% ET rate irrigated crop and 17-25% over rainfed crop. The soil heat flux was varying from 1.6 to 8, 1 W m⁻².

Table 2. Micro-meteorological observations (12.00 h IST) over sesame crop at Jodhpur

Date of observations	Solar radiation (W m ⁻²)	Net radiation (W m ⁻²)	Albedo (%)	Soil heat flux (W m ⁻²)
100% ET rate irrigated				
12.8.2009	1193	608	24	5.3
11.9.2009	1375	506	19	1.6
26.9.2009	1338	560	19	6.8
4.8.2010	1564	739	18	4.0
20.9.2010	864	532	25	2.5
50% ET rate irrigated				
12.8.2009	1193	664	17	5.7
11.9.2009	1375	617	17	5.7
26.9.2009	1338	584	19	8.1
4.8.2010	1037	692	22	2.5
20.9.2010	826	810	23	3.1
Rainfed				
12.8.2009	1193	659	20	6.4
11.9.2009	1375	612	18	5.1
26.9.2009	1338	615	17	5.7
4.8.2010	1037	732	18	3.9
4.8.2010	900	556	25	4.0

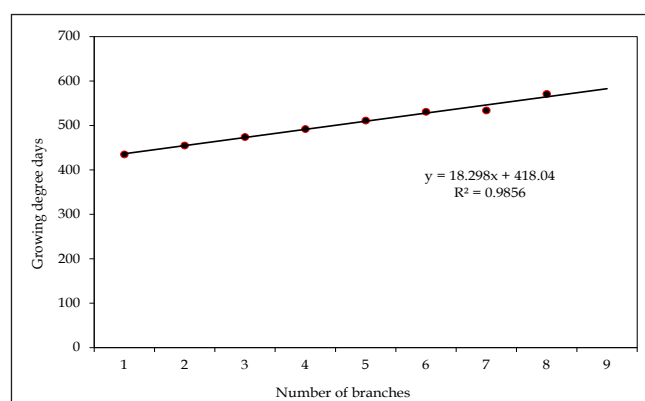


Fig. 4. Growing degree days vs. branch initiation in sesame crop.

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