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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 10 (3): 421-426, 2007
ISSN 1028-8880

The Effect of Water Deficit on Yield and Yield Components of Safflower (*Carthamus tinctorius* L.)

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Abstract: The aim of this study carried out in Shahid Chamran Ahwaz, University, in 2001-2002 to determine the effect of different forms of irrigation on the safflower (*Carthamus tinctorius* L.) yield and yield components. Information was needed on application time of irrigation water on cultivars of safflower (*Carthamus tinctorius* L.). Increasing competition for water supplies and rising costs of applying water make efficient irrigation important. Yield and water use of safflower were evaluated on silt loam soil. Deficit irrigation treatments; I_1: normal irrigation, I_2: cutoff irrigation in budding period, I_3: cutoff irrigation in flowering period (blooming), I_4: cutoff irrigation in maturity period, were examined in Randomized Complete Block Design (RCB) with three replications. In this field experiment irrigation regimes were the main plots and cvs (ARAK 28, ESFAHAN LOCALITY and FO2 cvs) were as sub plots. The plant height, the plant head number, the 1000 seed weight, and the seed yield were measured in this experiment. The different irrigation regimes had a significant effects ($p<0.05$) on the seed, the crude oil yields (kg ha^{-1}), seed number per boll, harvest index, total dry weight. The highest seed yield (2679 kg seed ha^{-1} in cv. ESFAHAN Lo.) and the crude oil yield (855 kg oil ha^{-1} in cv. ARAK) were obtained from the I_1 irrigation regime. I_3 gave the lowest seed yield (1499 kg seed ha^{-1} in cv. FO2) and the crude oil yield (449 kg oil ha^{-1} in cv. FO2). I_1 gave the highest oil percentage (35% in ARAK cv.) and the lowest (27.4% in FO2 cv.) obtained in I_4. The different between cvs were significant in number of boll per plant, number of seed per boll, the 1000 seed, high, number of branch per plant, seed yield (kg ha^{-1}), crude oil yield and total dry weight.

Key words: Safflower, water deficit yield, yield components, oil yield

INTRODUCTION

It is known that one of the essential nutrients in human consumption oil or fat is applied from the plant and animal sources. Oilseed crops are grown throughout of Iran for use as oils. The importance of oil plants same safflower in Iran agriculture and economy is also getting increased. Safflower is not a very selective for soil and climate; it can be even produce in arid lands (Tuncturk and Yildirim, 2004). Therefore many cvs of safflower are adapted to the longer growing season and warmer temperature (Johnston *et al.*, 2002). Most oilseed crops have an indeterminate growth habit; adaptation is influenced by tolerance to high temperature and drought stress and by crop management to take advantage of optimum environmental conditions for flowering and seed fill. The increasing area of oilseed crop production is an indication of the success of plant breeders and agronomist in developing suitable cultivars and production methods in semiarid region (Miller *et al.*, 2002). Oil content of safflower seed ranges from 35 to 40%. There are two types of safflower cultivars: those producing oil high in oleic or monounsaturated fatty acid and those high in linoleic polyunsaturated fatty acid (Berglund *et al.*, 1998).

The lack of oil in Iran has been met by imports that have entailed considerable costs. To make up for the lack of oil in Iran, oil seed production can be increased by growing oil plants in dry land farming or area with deficit water. According to annual precipitation many regions in Iran suffer from water deficit. The water deficit is common in arid and semi- arid regions where rainfall is insufficient to give enough water to plants (Pessarakli, 1999). Under water deficit it is important the time of apply water (irrigation) to maintain and/or improve soil water availability to crops (Van Horn and Van Alpen, 1990). The objective of this study was to test the hypothesis that although annul precipitation in Iran has variation in period, time and content but to decrease the oilseed import to Iran is this possible that use the new region with

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water deficit. Also could be produced oil seed by safflower in this area. In addition what is the effect of water deficit in different stage of reproductive period on yield components, seed yield and oil crude percentage of safflower.

MATERIALS AND METHODS

This study was carried out at the experimental farm of the Department of Agronomy and crop breeding faculty of Agriculture shahid Chomran University Ahwaz Iran in 2001-2002. The Climatic data of the region are representing in Table 1. The soil has clay-loam texture and low organic matter (Table 2).

The study was established using a Randomized Block Design with three replications. The time of water deficit (irrigation time) were placed in the main plots and including: I_1: normal irrigation, I_2: cutoff irrigation in blooming period, I_3: cutoff irrigation in flowering period, I_4: cutoff irrigation in maturity period. Two Iranian varieties of safflower, local ARAK 2811, local ESFAHAN and one introduce variety, FO2, were used in this study as sub plots.

Cultivars were planted in the middle of December (2001). All seed-beds were prepared with conventional tillage. Fertilizer was applied based on soil testing. Planted in dry soil in middle of December, the seed was germinated by applying irrigation water in the furrows until the soil was saturated. This method of planting, with variations, is a common practice among safflower growers in Iran, The plots were 7 rows, 0.5 m apart and 4 m long with guard rows on each side and about 0.5 m row of excess plants at each end. Soil moisture content in terms of percentage, based on dry soil was determined gravimetrically to depth of 0-30 and 30-60 cm at intervals during the budding stage and maturity.

Observations were carried out on 5 central rows and 0.5 m from both ends of the rows was left as it represented the border effect. Data collected included achene yield (obtained by combining the five center rows at each experimental unit), biological yield or dry weight were measured after drying samples at 70°C for 48 h in an air oven (Schuurman and Goedewaagen, 1971; Veli *et al*., 1991) harvest index [(achene yield/biological yield 100], plant height (distance from the ground level to the plant apex recorded at maturity). The yield components number of capitula per plant, achenes per capitulum and achene weight were obtained from six selected plants in each experimental unit. To determine oil content, samples were dried at 110°C for 3 h and then allowed to cool overnight.

The oil content was determined on a theoretical 0% moisture basis, using Nuclear Magnetic Resonance Spectroscopy (NMR) (Collins *et al*., 1967). For hull percentage determination, achenes were dried, weighed and then soaked for 48 h to allow hull separation. The hull samples were weighted and percentage of hull was determined. Oil Yield was calculated at the product of oil content and achene yield. Oil yield was calculated by multiplying oil content and the seed yield of each plot. In each plot, 4 groups of 100 seeds were weighed and their means were multiplied by 10 to calculate 1000-seed weight.

Height of sprout was measured with the base as the point where the first lateral branch arose from the stem, Result was tested in variance analysis and means were grouped in Duncan Multiple Comparison Test.

RESULTS AND DISCUSSION

Safflower plants responded to irrigation. Water deficit produce the same visual stress symptoms e.g. reduce plant size, change in leaf color and shortened leaf life (Day

Table 1: Climatic data of experimental farm of Ahwaz University in 2001 (in growth period)*

		Temperature (°C)			
Months	Precipitation (mm)	Min.	Average	Max.	Evapotranspiration (%)
October	3.5	19.70	27.63	35.56	119.4
November	10.7	11.10	18.80	26.50	97.2
December	96.4	12.06	16.60	21.15	82.6
January	28.5	6.66	11.37	16.08	78.3
February	23.3	8.23	14.15	20.07	62.4
March	2.3	12.66	19.49	26.32	77.5
April	37.8	17.31	23.47	29.63	170.4
May	6.1	25.64	32.24	38.85	248.1
June	0.0	25.46	34.70	43.95	446.0

* Taken from the recording of irrigation Department in Agriculture faculty of Ahvaz

Table 2: Result of some chemical and physical analysis of experimental soil*

Depth (cm)	Potassium (ppm)	Phosphor (ppm)	Nitrogen (%)	Organic matter (%)	EC (mmos/cm)	pH	Texture
0-30	155.7	10.2	0.035	0.58	3.95	7.70	Sandy loam
30-60	113.5	5.6	0.045	0.46	2.91	7.68	Sandy loam

* Soil analysis was done at the laboratories of soil science department

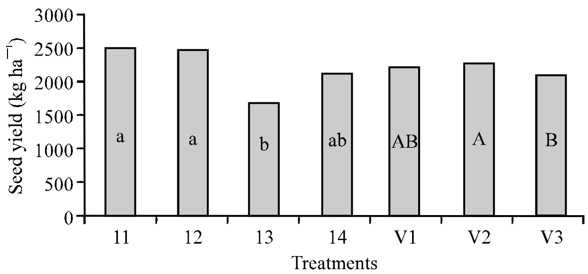

Fig. 1: Effect of treatments on seed yield Irrigation regime = I1: normal irrigation, I2: cutoff irrigation in budding period, I3 cutoff irrigation in flowering period (blooming), I4: cutoff irrigation in maturity period; cultivars = V1: ARAK, V2: ESFAHAN, V3:FO2. Means with the same letters are not significantly different (small letters = Duncan 0.01 between irrigation treatments, capital letters = Duncan 0.05 between cultivars treatments)

and Intalap, 1970; Hang and Miller, 1983; Johnson, 1953; Kramer, 1963). Irrigation treatments terminated at physiological maturity of the crop rather than harvest maturity which occur at a latter date. Physiological maturity represents the end-point of the influence of soil water on the weight of seed. An estimated date for physiological maturity is required for optimum timing of the final irrigation to supply the crop needs at this stage and to avoid excessive irrigation (Jones and Tucker, 1968). Other consideration involved in the decision to terminate irrigation includes the development of the estimation of the quantity of irrigation (kc) (Jensen and Middlenton 1970). The yield attributes like capitula/plant, seed/capitula and seed weight/capitulum's were significantly influence by irrigation schedules (Table 3).

Maximum number capitula/plant and seed/capitulum were produced by crop receiving I_3 (cut-off irrigation in blooming period) and I_1 (normal irrigation) irrigation respectively, whereas the highest the 1000 seed weight expressed by I_1 (normal irrigation). Deficit water at I_3 (cut-off irrigation in blooming) resulted in reduced development of seed yield due to induction of less seed weight which in turn provided potential sites for seed yield attributes. The maximum seed yield was recorded with I_1 and ESFAHAN local. Variety (Fig. 1-3), whereas the highest crude oil and oil percentage obtained by I_1 at ARAK cv and the lowest were recorded in I_3 with FO2 cv (Table 3).

Average seed yield for the irrigation regime treatments ranged from 1499.2 (I_3) to 2678.8 (I_1) (kg ha^{-1}). These results illustrate the capacity of safflower to compensate for variation in irrigation. Maximum/significant and minimum seed yield per plant were achieved at the I_1 (ESFAHAN cv) and I $_3$(FO2 cv) respectively. In all cultivars, I_3 produced significantly lowest seed yield (Table 3).

Yield components: The primary yield components of safflower are number of capitula per plant, number of seed per capitulum and seed weight. Even though yield components are under genetic control, they do respond with various degrees of flexibility to water deficit or irrigation regime (Table 3). The analysis of variance indicates that number of seeds per capitulum (not capitula per plant) decreased by changing the irrigation regime from I_1 to I_2 or I_3 (Table 3), while variation the capitula per plant was not same that. The number of seed per capitulum produced at the deficit moisture of soil (I_3) was significantly less than at the other irrigation regimes (I_1, I_2

Table 3: Effect of irrigation regime yield and its components oil percentage and oil content

Irrigation regime	Verities	1,000-seed weight	Seed/capitulum	Capitula/plant	Seed yield (kg ha^{-1})	Oil content (kg ha^{-1})	Oil (%)
I_1	ARAK	36.3	35.9	18.9	2458.9	865.1	35.2
I_2		34.5	34.9	18.4	2498.9	826.3	33.2
I_3		36.4	23.3	17.6	1720.9	561.3	32.5
I_4		30.9	33.1	19.7	2155.2	674.7	31.4
I_1		30.4	37.3	23.5	2678.8	854.1	31.8
I_2		29.7	35.1	21.7	2490.6	761.2	30.2
I_3	ESFAHAN	31.8	25.4	25.7	1844.7	558.9	30.4
I_4		26.7	34.4	23.5	2172.2	666	30.3
I_1		32.7	32	21.4	2373	708.4	29.5
I_2		32.8	29.2	20.4	2344	684.9	29.2
I_3	FO2	34.3	17.4	22.8	1499.2	449	30
I_4		31	31.8	23.4	2049.5	564.9	27.4

Table 4: Means of variables affected by irrigation regimes

Irrigation regime	Husk of seed (%)*	Harvest index (%)**	Total dry matter (g m^{-2})**	Capitula/ plant (n.s)	Seed/ Capitulum**	1000-seed. weight (g) *
I 1	43.0ab	28.4a	1209.8a	21.3	35.1a	33.1a
I 2	41.1b	28.1a	1139.2ab	20.2	33.1b	32.3ab
I 3	43.7ab	23.4b	940.5c	22.0	22.0c	34.2a
I 4	44.4a	25.7ab	1118.5b	22.2	33.1b	29.5b

Means with the same letters are not significantly different, (**= Duncan 0.01, *= Duncan 0.05, (n.s) = non significant)

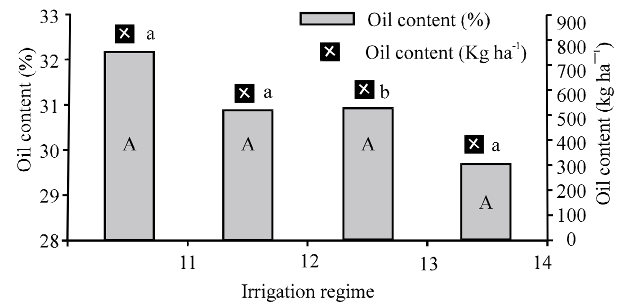

Fig. 2: Effect of irrigation regime on oil content. Means with the same letters are not significantly different (Duncan 0.05 small letters for oil content (kg ha^{-1}) capital letters for oil content (%)

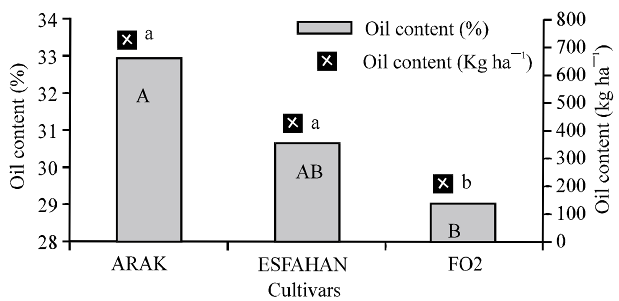

Fig. 3: Effect of cultivars on oil contents. Means with the same letter are not significantly different (Duncan 0.05 small letters for oil content (kg ha^{-1}) capital letter for oil content (%)

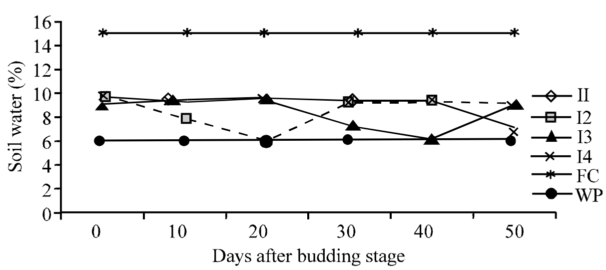

Fig. 4: Percentage of soil water at depth 0-30 cm

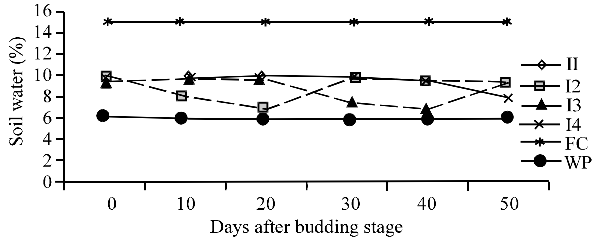

Fig. 5: Percentage of soil water at depth 30-60 cm

and I_4) (Table 4). Inter-and intraplant competition for water necessary and nutrient for growth and development increase as irrigation regime changed from I_1 to others (I_2, I_3, I_4) and plants are not able to express their maximum genetic potential. Seed weight was significantly influenced by changed the irrigation regime from I_1 to I_4. Environmental conditions such as water deficits and interplant competition can adversely influenced seed development by inhibiting photosynthesis and other metabolites required during the seed filling stage. The lightest seed weight (1000 seed weight = 29.5 g) was obtained in I_4 treatment. The irrigation regime cultivar effect was significant ($p \leq 0.05$) for three yield components (Table 3).

The cultivar ESFAHAN produced significantly more capitula per plant (25.7) than the other cultivars in all irrigation treatment (Table 3). The other cultivars did not differ significantly from each other, except that ARAK cultivar (in I_3) produced significantly fewer capitula. Per plant (17.6). Cultivar ESFAHAN was, however among the highest producers of seed per capitulum in almost all irrigation regime treatments.

ARAK cultivar had higher seed weight than the other cultivars except that in FO2 cv in I_4 (Table 3). ESFAHAN cv produced lighter seed in all irrigation regime treatments.

Oil and hull percent: The irrigation regime (I_1, I_2, I_3, I_4) tested did not have a significant safflower seed oil (%) content (Table 3), however the seed oil content (kg ha^{-1}) in irrigation regime×cultivar interaction effects were significant ($P \leq 0.05$). The significant interactions were associated with the magnitude of differences seed yield (kg ha^{-1}). Across irrigation regime treatments the seed oil content (kg ha^{-1}) of ARAK cultivar (in I_1 with 865.1 kg^{-1} ha) and FO2 cultivar (in I_3 with 449 kg ha^{-1}) was significantly higher and lower, respectively, than the other cultivars (Table 3 and Fig. 2 and 3)

Several environmental factors can influence the achene oil content of safflower genotypes. (Fick, 1978) reported that climatic conditions, such as temperature and precipitation (or different soil moisture and water deficit) can influence oil content of sunflower. In addition, the combination of yield components in a given plant determines the allocation of photosynthesis and seed oil content (Grafius, 1964). Both kernel oil content and hull percent influence seed oil content. No significant differences among cultivars in the hull percent and oil content (%) of the kernel were found (Fig. 2 and 3). Results suggest that differences in oil content (kg ha^{-1}) of the safflower cultivars tested were due mainly to differences in seed production. Analysis of variance indicates significant irrigation regime cultivar effects. The significant interaction indicates that the cultivars production of oil (kg ha^{-1}) depend on the time water

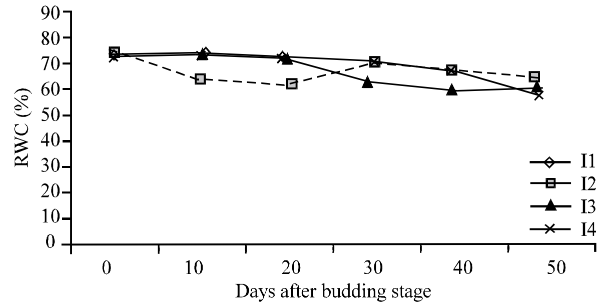

Fig. 6: Percentage of leaf Relative Water Content (RWC)

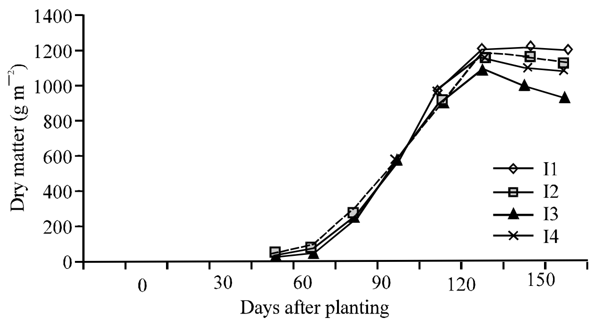

Fig. 7: Trend of total dry matter in ARAK variety

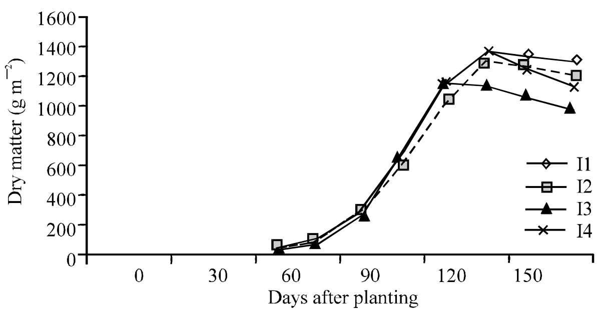

Fig. 8: Trend of total dry matter in Esfehan variety

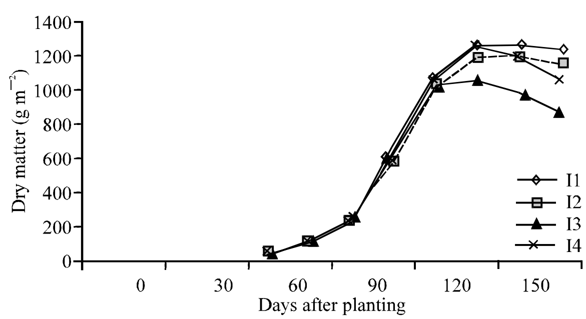

Fig. 9: Trend of total dry matter in FO2 variety

deficit in grain filling stage, for example in all cultivars produced higher oil yield (kg ha^{-1}) at I_1 and I_2 treatments, where the plants were under more sever water deficit in I_3 and produced the lowest oil (Fig. 4-6).

Examination of soil moisture data revealed that, during grain filling stage in I_3 treatment, water supply in soil was not large enough to increasing the seed yield or RWC to result more seed yield production and oil yield. This study revealed that effect of water deficit in the oilseed production of the investigated safflower varieties were showed there existed variation between the varieties in terms of oil content. In our study, the safflower varieties (e.g., ARAK cv) we used could keep up and could be produced oil content satisfied with the soil by water deficit in the late growth season. Moreover if the cultivation of safflower in new region with water deficit soil, at the end of growth period is required, the ARAK variety should be preferred (Fig. 7- 9). This cultivar may be more efficient in the conversion of photosynthates into grain or in the allocation of photosynthates into reproductive rather than vegetative growth. While, in many cultivars, water deficit at reproductive stage might have resulted insufficient supply of photosynthesis for better filling already created greater sink capacity with the highest soil moisture (Bostia *et al*., 2003).

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