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The Effect of Drought Stress on Yield, Yield Components and Seed Oil Content of Three Autumnal Rapeseed Cultivars (*Brassica napus* L.)

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ABSTRACT
Water deficiency has adverse effect on vegetative and reproductive stages of rapeseed. Hence, the objective of this field experiment was to examine the effects of irrigation intervals on yield, yield components and oil seed content of three autumnal rapeseed cultivars. An annual field experiment was conducted on a sandy-loam soil at the Islamic Azad University, Maybod Branch in 2006-2007. A split-plot experiment carried out in RCBD with four replications. The irrigation intervals were placed in the main plots including: I_1: 7 days, I_2: 10 days and I_3: 14 days and Okapy, Zarfam and Sarigol cultivars were as subplots. Planting date was September 2006. Fertilizer was applied based on soil testing for all treatments. Irrigation treatments were applied on March 2007 after rosette stage and plant were harvested on July 2007. The following measurements were carried out: seed yield, the number of lateral branches, plant height, the number of siliques per plant, the number of seeds per silique, 1000-seed weight and seed oil content. Base on results, there were significant differences in seed yield between the irrigation intervals and cultivars. The I_1 and I_2 treatments produced a significantly higher seed weight than I_3. Sarigol and Zarfam produced a significantly higher seed yield than Okapy. The irrigation intervals and cultivars were not significant on seed oil content. On the I_1, I_2 and I_3treatments seed oil percentage were 37.58%, 38.38% and 35.93%, respectively and on the Sarigol, Zarfam and Okapy were 37.58%, 37.58% and 35.51% respectively. It is concluded from the present study that 7 days interval and Zarfam cultivar produced the highest seed yield.

Keywords: Rapeseed, Drought stress, Irrigation interval, Yield, Yield component, Oil content

INTRODUCTION

The deficit of feed oil in Iran has been observed by imports that have entailed considerable costs. For making up the deficit of feed oil in Iran, oil seed production can be increased by planting oil plants in dry land areas with deficit water. According to annual precipitation, many regions in Iran suffer from water deficit. Under water deficit it is important the time of irrigation to maintain and /or improve soil water availability for crops (Van Horn and Van Alpen, 1990). Drought, salinity, heat and freezing are environmental conditions that cause adverse effects on the growth of plants. Water deficit more than other stresses limits the growth and the productivity of crops (Yamaguchi-Shinozaki *et al*., 2002). Yield of *Brassica napus* (Jensen *et al*., 1996; Kumar and Singh, 1998), *B. juncea* and *B. rapa* (Sharma, 1992; Wright *et al*., 1995) decreased due to drought stress. The effect of drought stress is a function of genotype, intensity and duration of stress, weather conditions, growth and developmental stages on rapeseed (Robertson and

Holland, 2004). Water deficiency has adverse effect on vegetative and reproductive stages of oil seed rape crops. Mailer and Cornish (1987) demonstrated that adverse effect of water stress was more during reproductive growth of rapeseed than vegetative growth. Rao and Mendham (1991), Hang and Gilliard (1991) and Latifei (1995) found that flowering of rapeseed is a critically sensitive stage to water stress. Malekei and Sinaki (2005), Clarke and Simpson (1978), Latifei (1995) and Triboy and Renard (1999) showed that drought stress decreased the number of siliques per plant. Malekei and Sinaki (2005) and Clarke and Simpson (1978) found the irrigation intervals affected 1000–seed weight. With increasing irrigation interval, 1000–seed weight will decreased. Hassanzadeh *et al*. (2005) demonstrated that yield components of rapeseed affected by irrigation interval and cultivars.

Under dry land conditions, Henry and Macdonald (1978) reported that severe drought decreased oil content of rapeseed. Malekei and Sinaki (2005) and Krogman and Hobbs (1975) demonstrated that irrigation intervals had significant effect on oil percentage. Siavash *et al*. (2005) measured eight kinds of fatty acid in oil of rapeseed that were different among cultivars. Daun *et al*. (1985) found that high temperature decreased unsaturated fatty acids in rapeseed oil. Rapeseed oil consists of four important fatty acids: palmitic acid, oleic acid, linoleic acid and linolenic acid. linolenic acid in rapeseed oil is more than the other plant oils. The growth, especially reproductive growth, of rapeseed cultivars is exposed to drought stress in many areas of Iran. Hence, the objective of this field experiment was to study the effects of irrigation intervals on yield, yield components, seed oil quantity and quality of rapeseed cultivars.

MATERIALS AND METHODS

This study was carried out at the research station of the Islamic Azad University, Maybod-Iran at 2006-2007. The meteorological data of the region are representing in Table1. The soil was sandy-loam texture (Table 2). The study was established using a split-plot layout in RCBD with four replications. The irrigation intervals were placed in the main plots including: I_1: 7 days, I_2: 10 days and I_3: 14 days and three varieties of rapeseed (Okapy, Zarfam and Sarigol) were used as subplots. For all treatments, N: P: K fertilizers were applied at a rates of 200:80:80 kg/ha, respectively. P, K and 1/2 of N were applied per plant and incorporated. Other 1/2 of N was used at the beginning of the flowering. Irrigation treatments were applied after rosette stage. Plants were irrigated every 7, 10 and 14 days, consuming 6750, 5250 and 4500 m^3/ha/season, with 9, 7 and 6 times of irrigation, respectively (Table 3). Grass and broad leaf weeds were hand weeded during the growth season. Plant harvests were carried out on July 2007. Observations were carried out on 2 central rows and 0.5 m from both ends of the rows was left as it represented the border effect. The following measurements were carried out: seed yield (plants were harvested from 3 m^2 of central rows with ignoring border effect then seeds separated and weight from individual plots (14% moisture), the number of lateral branches (18 plants of every individual plots were selected and the number of branches were countered in every plant), plant height(distance from the ground level to the plant apex was recorded at the maturity from 18 plants in every individual plot), the number of siliques per plant (18 plants of every individual plots were selected and the number of siliques in every plant were countered (with at least one seed), the number of seeds per silique (18 plants of every individual plots selected and the number of seeds were countered from 5 siliques in every plant) and 1000-seed weight(seed counter was used to count the number of 100-seed). Seed oil quantity and quality were determined by succelet and gas chromatography methods, respectively.

The experimental data were statistically analyzed for variance using the SAS software. When analysis of variance showed significant treatments effects, Duncan multiple range test was applied to compare the means (at the 5% probability level).

Table1. Meteorological data of the experimental site in 2006 – 2007

Month	Highest temp. (°c)	Lowest temp. (°c)	Rain fall (mm)	Evaporation (mm)
Sep	38	10.4	.	14
Oct	38	10	.	7.75
Nov	31.4	-0.4	13.6	5.6
Dec	16	-6.6	25.1	2.25
Jan	18.4	-12.4	1.5	2.03
Feb	23.8	-7.0	2.2	3.65
Mar	26.8	-2.8	4.5	5.03
Apr	32.8	2	12.5	6.29
May	39.6	9.8	0.2	13.54
Jun	44.5	14.6	.	15.62
Jul	44.5	19.6	.	16.36

Table 2. Some physical and chemical properties of experimental soil field at depth 0 – 30 cm

Sand %	Silt %	Clay %	Texture	pH
15.4	66.2	18.4	Sandy loam	7.8

EC (dS/m)	Organic Carbon %	Total N%	Available P(ppm)	Available K(ppm)
2.3	0.4	0.038	6.37	270

Table 3.Volumes of water in the evaluated three irrigation regimes

Irrigation regime	Volume of water (m^3/ha) used before treatments application	Volume of water (m^3/ha) used after treatments application	Total volume of water (m^3/ha) used during season	Irrigation number
Irrigation every 7days	2250 m^3/ha	4500 m^3/ha	6750 m^3/ha	9
Irrigation every 10 days	2250 m^3/ha	3000 m^3/ha	5250 m^3/ha	7
Irrigation every 14 days	2250 m^3/ha	2250 m^3/ha	4500 m^3/ha	6

Table 4. Mean comparison effect of irrigation intervals and cultivars on plant height , number of branches and siliques/plant , number of seed per silique , 1000 – seed weight and seed yield

Traits / Treatments	Plant height (cm)	Branches /plant	Siliques/ plant	Seed/ silique	1000-seed weight (g)	Seed yield (kg/ha)
Irrigation intervals						
7 days	133.25 a	9.70 a	291 a	26.28 a	3.14 a	3374 a
10 days	128.98 a	10.21 a	291 a	25.50 a	3.60 a	3046 a
14 days	126.63 a	9.41 a	257 b	26.01 a	3.38 b	2652 b
Cultivars						
Sarigol	135.17 a	10.51 a	318 a	24.33 b	3.47 b	3294 a
Zarfam	134.86 a	9.63 b	264 b	27.00 a	3.82 a	3238 a
Okapy	118.83 b	9.18 b	256 b	26.46 a	3.43 b	2836 b

Table 5. Mean comparison effect of irrigation intervals and cultivars on seed oil percentage and fatty acids

Traits / Treatments	Seed oil (%)	Palmitic acid (%)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)
Irrigation intervals					
7 days	37.58 a	3.87 b	84.47 a	8.92 a	2.94 a
10 days	38.30 a	4.20 a	84.29 a	9.35 a	2.19 a
14 days	35.93 a	4.29 a	84.59 a	9.16 a	2.50 a
Cultivars					
Sarigol	37.58 a	3.98 b	84.78 a	10.38 a	2.82 a
Zarfam	37.58 a	4.29 a	84.49 a	9.06 a	2.17 a
Okapy	35.51 a	4.10 b	84.09 a	7.99 b	2.64 a

RESULTS AND DISCUSSION

Morphological traits

The irrigation intervals were not significant on the number of lateral branches and stem height (Table 4). Higher plant height was reported at I_1 (133.25 cm) and then I_2 (123.98 cm) and I_3 (126.63 cm), respectively. On the I_1, I_2 and I_3, number of lateral branches were 9.7, 10.21 and 9.41, respectively. Other studies reported similar results (Al-Barrak, 2006).

Number of lateral branches and plant height showed significant difference amongst cultivars (Table 4). Sarigol (10.51) produced higher number of branches than Zarfam (9.63) and Okapy (9.18) also Sarigol (135.17 cm) and

Zarfam (134.86 cm) had significant difference with Okapy (118.83 cm) from plant height.

Yield components

Significant differences in the mean number of siliques per plant observed amongst the different irrigation intervals. The average number of siliques per plant decreased with increasing irrigation intervals (Table 4). The I_1 (291) and I_2 (290) treatments produced a significantly higher number of siliques than I_3 (257). These results are consistent with those reported by Wright *et al*. (1988), Aljaloud *et al*. (1996), Nielson (1997) and Leilah *et al*. (2000). The higher number of siliques/plant under shorter intervals could be attributed to higher number of flower/plant. Significant differences in the mean number of siliques per plant were observed amongst the cultivars (Table 4). Sarigol (318.3) produced a significantly higher number of siliques than Zarfam (263.9) and Okapy (256.7).

Significant differences were found in the mean number of seeds per silique amongst the cultivars but there was no significant difference amongst irrigation intervals (Table 4). On the I_1, I_2 and I_3 number of seeds per silique were 26.28, 25.5 and 26.01, respectively. Zarfam (27) produced more seeds per silique than Okapy (26.46) and Sarigol (24.33).

Significant differences were found in 1000–seed weight amongst the irrigation intervals and cultivars (Table 4). The shortest interval (I_1) (3.74 g) produced highest 1000–seed weight than I_2 (3.6 g) and I_3 (3.38 g). There was not significant different between I_1 and I_2. These results support the findings of Tayo and Morgan (1975), Malekei (2005) and Clark and Simpson (1978). Zarfam (3.82 g) produced a significantly higher 1000–seed weight than Sarigol (3.47 g) and Okapy (3.43 g). These results are consistent with those reported by Shiranirad and Dehshirei (2002). Interaction effects showed that Zarfam in 7 days and Okapy in 14 days produced highest and lowest 1000-seed weight, respectively (Table 7).

Yield

There was significant difference in seed yield between the irrigation treatments. The I_1 (3374 kg/ha) and I_2 (3046 kg/ha) treatments produced a significantly higher seed yield than I_3 (2652 kg/ha). Cultivars had significant differences. Sarigol (3294 kg/ha) and Zarfam (3238 kg/ha) produced a significantly higher seed yield than Okapy (2836 kg/ha) (Table 4).

In the current study, seed yield of rapeseed increased in response to shortening irrigation intervals with maximum yield (3374 kg/ha) being attained with I_1 days irrigation intervals. However, there were no significant differences between I_1 and I_2. This indicated that shortening irrigation intervals (increased in seed yield) was not proportional. This increasing was 15% between I_3 and I_2, 11% between I_2 and $I_1$and it was 27% between I_1 and I_3. The obtained seed yield under this irrigation was comparable with by Leilah *et al*. (2003), Wright *et al*. (1988), Elsaidi *et al*. (1992), Clarke and Simpson (1978), Hassanzadeh *et al*. (2005) and Hang and Gilliard (1991). The results of higher seed yield for I_1 than I_3 could be largely due to the greater number of siliques per plant (Table 4).

The higher seed yield in rapeseed may be associated with higher leaf area (Wright *et al*., 1988; Nielson, 1994; Howell, 2000). Although leaf area was not estimated in the current study, leaf area is largely expected to be associated with both plant height and number of branches/plant. Interaction effects showed that Zarfam in 7 days produced highest yield and Okapy in 14 days produced lowest yield than the others (Table 7).

Yield quality

Irrigation interval and cultivars did not significantly affect seed oil content (Table 5). The highest oil content of 38.38% was found at I_2 with no significant differences detected between I_1 (37.58 %) and I_3 (35.93 %). The longer interval of irrigation reduced the oil content relative to the lower moisture content available. Similar results have been reported in canola (Barszczak *et al.*, 1993). Sarigol, Zarfam and Okapy produced 37.58%, 37.58% and 35.51%, respectively. Four fatty acids were measured in seed oil consist of: palmitic acid, oleic acid, linoleic acid and linolenic acid. The effects of irrigation intervals were not significant on the oleic acid, linoleic acid and linolenic acid, but it was significant on the palmitic acid. I_3 (4.29%) and I_2 (4.2%) had a significantly higher palmitic acid than I_1 (3.87%). The effects of cultivars were not significant on the oleic acid and linolenic acid, but it was significant on the palmitic acid and linoleic acid. Zarfam (4.29%) had a significantly higher palmitic acid than Okapy (4.1%) and Sarigol (3.98%). Sarigol (10.38%) and Zarfam (9.06%) had a significantly higher linoleic acid than Okapy (7.99%). Similar results have been observed by Siavash *et al*. (2005). The mean of fatty acids were: palmitic acid: 4.12%, oleic acid: 84.2%, linoleic acid: 9.14% and linolenic acid: 2.5%.

Table 6. Effects of the interaction between irrigation intervals and cultivars

Traits / Irrigation*Cultivar	Linolenic acid (%)	Linoleic acid (%)	Oleic acid (%)	Palmitic acid (%)	Seed oil (%)
7days*sarigol	3.28 a	11.16 a	87.28 a	3.81 a	38.68 a
7days*zarfam	2.45 a	7.53 a	86.18 a	4.02 a	42.68 a
7days*okapy	3.10 a	8.09 a	79.95 a	3.80 a	31.41 a
10days*sarigol	2.34 a	10.14 a	83.78 a	3.98 a	37.37 a
10days*zarfam	2.00 a	9.61 a	84.21 a	4.39 a	39.81 a
10days*okapy	2.24 a	8.31 a	84.90 a	4.24 a	37.93 a
14days*sarigol	2.84 a	9.86 a	83.29 a	4.15 a	36.72 a
14days*zarfam	2.08 a	10.05 a	83.09 a	4.45 a	33.91 a
14days*okapy	2.57 a	7.58 a	87.42 a	4.27 a	37.21 a

Table 7. Effects of the interaction between irrigation intervals and cultivars

Traits / Irrigation*Cultivar	Seed yield (kg/ha)	1000-seed weight (g)	Seed/ silique	Siliques/ plant	Branches /plant	Plant height (cm)
7days*sarigol	2910 ab	3.59 ab	23.37 a	299a	10.10 a	139.5 a
7days*zarfam	3945 a	4.08 a	27.98 a	293a	9.65 a	139.1 a
7days*okapy	3267 a	3.56 ab	27.50 a	281a	9.35 a	121.3 a
10days*sarigol	3332 a	3.27 ab	24.75 a	355a	11.45 a	128.5 a
10days*zarfam	2970 ab	3.90 ab	25.53 a	256ab	9.80 a	134.9 a
10days*okapy	2838 ab	3.63 ab	26.24 a	261ab	9.40 a	123.6 a
14days*sarigol	3135 a	3.54 ab	24.88 a	300a	10.00 a	137.6 a
14days*zarfam	2730 b	3.50 ab	27.51 a	243b	9.45 a	130.6 a
14days*okapy	2091 b	3.10 b	25.67 a	229b	8.80 a	111.7 a

CONCLUSION

It is conclusion from the present study that water stress on rapeseed mainly decreases seed yield by reduction of the silique number per plant. The number of seeds per silique changed less than the siliques per plant. Interaction effects showed that Zarfam in 7 days irrigation interval produced highest seed yield than the others.

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