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Research Article

EFFECT OF IRRIGATION REGIMES ON YIELD COMPONENTS AND OIL QUALITY OF DIFFERENT CULTIVARS OF RAPESEED (*BRASSICA NAPUS* L.)

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ABSTRACT
Rapeseed is one of the most valuable plants in the world which is highly regarded in terms of oil and protein. Plant growth and yield have been limited by several biotic and abiotic environmental stresses in many parts of the world. Drought stress is one of the main obstacles to the successful production of crops. To investigate the effects of water stress on yield and oil of rapeseed varieties, a split plot experiment was carried out in a randomized complete block design with three replications. Irrigation was considered as the main plot in the four levels of normal irrigation (I-0), cut irrigation after stem elongation stage (I-1), cut irrigation after the flowering stage (I-2), and cut irrigation after the podding development (I-3). The sub plot was rapeseed cultivars included 6 cultivars (KR4, HW113, HW118, L5, SW101, and HW101). Approaching to physiological maturity, some traits were measured including; plant height, stem diameter, number of branches per plant, number of pods per plant, pod length, number of seeds per pod, 1000-grain weight, grain yield, biological yield, harvest index, seed oil content, oil yield, the glucosinolate, the erucic acid and the oleic acid content. According to the results obtained in this experiment, cut irrigation at flowering decreased the number of pods per plant. Drought stress at flowering stage resulted to decrease in plant flowering potential and so number of pods and the total number of grains per plant and finally leaded to reduction in grain yield and oil yield. Also, the stress during the stem elongation stage reduced dry matter production and its storage in vegetative organs and the ultimate yield declined due to this deficiency. The results revealed that the HW101 cultivar could be used as a suitable cultivar at regions with moisture limitation especially in stem elongation stage and the KR4 could be utilized as a proper cultivar at regions with drought stress in flowering stage and the L5 could be used in areas where may face the drought stress at the end of the planting season, so, rapeseed cultivation could be extended in the dry areas.

Keywords: *Rapeseed Plant, Yield Components, Rapeseed Oil, Drought Stress, Harvest Index*

INTRODUCTION
Rapeseed is a valuable oil plant that has attracted many attentions in recent years. Rapeseed is rich in protein and oil and the Rapeseed grains have about 40 to 42% oil. Edible rapeseed grain containing 43.6% of protein and amino acids, lysine, methionine and cysteine. Commercial rapeseed or canola has lower amount of glucosinolate and erucic acid than common rapeseed (Iqbal *et al*., 2008). Worldwide, the area under cultivation of rapeseed was changed from 7 million hectares in 1965 to 27 million hectares in 2005. It showed that almost every 20 years, the area under cultivation has been doubled. In 2005, China had the largest area under cultivation of rapeseed and followed by India, Canada, Europe and Australia in their next orders. Rapeseed supply approximately 12% of the protein of the world's food (Berry and Spink, 2006). Rapeseed cultivation in Iran was began in 1998 with substantial delay and 8,000 hectares area under cultivation and grain yield 0f 750 kg. It was welcomed by farmers and technical and commercial supporting, the cultivation of this crop was increased in a short time and its cultivation area reached to 73 thousand hectares with more than 155 kg/ha yield in 2003 (Anonymous, 2004). Plant growth and performance are limited by several biotic and abiotic environmental stresses in many parts of the world. In fact, the environmental stresses are the most important factors in reducing agricultural products in the world. If the environmental stresses would not have happened, the actual performance should be equal to

the potential yield of plants while the average yield of crops is about 10 to 20 percent less than their true potential and the stressors have a negative impact on agricultural production (Kafy and Mahdavy, 2007). Drought is the major obstacle to successful produce of agricultural crops. A combination of factors has led to a variety of drought and this variety can cause different mechanisms in living organizations (Monteneveus and Belhasken, 1996). The main reason of water stress in plants is the increase in the rate of water loss or insufficient water absorption or a combination of both that would cause to surpass the rate of water loss due to transpiration to water uptake by roots and continuing this conditions, the stress level increases (Hajeby and Heidary, 2005). Drought stress in plants causes delay in germination, reduction in rate and percentage of germination and seedling growth and the seeds that can have a proper rate and percentage of germination and good growth in radicle and plumule at drought stress condition, would have a better establishment and so more grain yield (Allen *et al.*, 1985). Extension of cell wall synthesis and protein synthesis in the fast-growing tissues is the most critical process in relation to water scarcity (Sadras and Milroy, 1995).

Desclauxe *et al.*, (2000), observed that the effect of drought stress and planting date on soybean. They stated that the plant height and yield components such as the total number of pods, the number of filled pods and seed weight decreased significantly and the average of plant height in vegetative and flowering stages was the most sensitive trait.

The different studies showed that there were a high correlation between yield and yield components of the irrigation and water consumption (Chay and Thurling, 1989). Drought stress affects the phenology of plants and thereby effects on yield and yield components (Desclauxe and Roumet, 1996). When the soil moisture reached to less than 50% of its available water during flowering to green ripening, the decrease in the grain yield occurred (Bernardo *et al.,* 1984). Flowering stage and the early stages of pods development were considered critical stages, i.e. the time of determining the number of pods and seeds of rapeseed plants in terms of need to water (Rao and Mendham, 1991). More than two irrigations were not suitable for rapeseed; meanwhile, this crop had a good response to irrigation at start of flowering (Soper, 1971). The yield components often measured at harvest time in order to determine the most important role in relation to difference between genotypes and treatments. In early and winter cultivation of rapeseed, a large number of pods was produced that the competition between them was high. In these cultivations, usually the chances of survive was more for seeds and pods in the upper part of the main stem, which was due to a better distribution of solar radiation

In the study of Pasban *et al.*, (1999) the water stress significantly decreased the number of pods per bushes within the yield components. The number of pods was affected by environmental factors more than seed weight and showed that the irrigation before flowering had no effect on harvest index. Jenses *et al.*, (1966) showed that soil drying in an environment with low evaporation power, had no significant effect on canola oil percentage but drought stress in sandy soil decreased the oil amount. The positive effect of irrigation on yield of spring rapeseed so that in control treatment (without irrigation) the yield was about 1 t/ha while in irrigated plots the yield reached to 2.5 t/ha. Kajedy (1992), have studied the changes of oil percentage and oil yield and the relation between the oil percentage and protein in 21 cultivars under irrigation and no-irrigation condition and showed that the average of grain yield and oil yield increased in irrigation condition. Among different environmental factors that effect on the amount of oil, irrigation could increase the amount of oil (Krogman and Hobbs, 1975). The quality characteristics of oil like protein and fat influenced by the water intervals (Chylinska, 1996). Functional or physiological efficiency and ability of a crop plant to total convert biomass (dry matter) to yield is known as harvest index (Suna *et al.,* 2003). The researches revealed that different cultivars of rapeseed had a significant difference in terms of harvest index and it depended on the environmental and genetic factors (Kolte *et al.*, 2000; Munir and Mc Neilly 1992).

Generally, harvest index was significantly reduced by water shortages in both vegetative growth and flowering stage and also in grain filling stage (Jensen *et al.*, 1996). Drought stress at flowering stage reduced plant height, dry weight, leaf relative water content, and pods number and length in spring varieties of rapeseed (Sheikh *et al.,* 2005).

Accordingly, this study was aimed to determine the impact of irrigation interruption at different stages of growth in rapeseed plant varieties on the properties and components of yield, and the amount and quality of rapeseed oil.

MATERIALS AND METHODS

This experiment was carried out in Karaj region, Alborz province, Iran with latitude of 35° and 59′ N and longitude of 50° and 75′ E and altitude of 1313 meters above sea level and its long-term average rainfall of 244 mm. In order to implement this study, an experiment was conducted in a split plot in a randomized complete block design with three replications. Irrigation as the main factor included four levels of irrigation; common irrigation (I-0), cut irrigation at stem elongation stage (I-1), cut irrigation at flowering stage (I-2), and cut irrigation at pod development (I-3). The sub plot was the rapeseed cultivars in 6 levels such as; HW113, KR4, HW101, SW101, L5, HW118. The trial was carried out in 72 experimental plots that each plot consisted of 6 line with 5 meter long and 30 cm spacing of and 5 cm between plants on lines. Approached the plant physiological maturity, some traits were measured such as; plant height, stem diameter, number of stems per plant, number of pods per plant, pod length, number of seeds per pod, 1000-grain weight, grain yield, biologic yield, harvest index, oil seed content, oil yield, the glucosinolate, the erucic acid and the oleic acid content. According to the analysis of soil (Table 1) and fertilizer recommendations, preceded to fertilization (a part of nitrogen fertilizer and all of phosphorus and potassium requirements) and broadcasted uniformly Treflan herbicide (Trifluralin) at a rate of 2.5 liters per hectare in the farm and the fertilizer and herbicide were mixed to soil by light disk tillage. To efficient use of nitrogen, the rest of the nitrogen fertilizer was added top-dressing at the beginning of stem elongation and the emergence of the first flower buds.

Table 1: The analysis of soil of the farm

Parameter	Level
pH	7.74
Organic Carbon (%)	0.64
EC (dS/m)	1.70
Nitrogen (%)	0.06
Soluble Phosphorus (mg/kg)	10.3
Soluble potassium (mg/kg)	275
Soil texture	Loamy clay

The planting operation was done by hand and the thinning operation was carried out at 2-6 leaf stage in order to achieve the proper plant density and remove weeds.

10 plants from each plot were randomly chosen to determine the traits such as plant height, number of seeds per pod, number of pods per plant and measurement was done based on the samples. At maturity, the plants were cut and exposed to the air in two separate categories within the plot were for 4 days in order to decrease the moisture up to 12%, then they were weighted by a precision scale and the biological yield of each plot were calculated in terms of kilograms per hectare.

To separate the seeds from the pods, the plants of each plot were put into the thresher then the seeds were weighted by a precision scale and the grain yield was estimated in terms of kilograms per hectare. To measure thousand seed weight, four samples of thousand seeds were randomly selected from each plot and were weighted and their average was recorded as the 1000-grain weight in terms of gram.

Harvest index is the function of grain yield to the total weight of crop. This attribute was determined, by dividing the grain yield to the total weight of the biomass (biologic yield) and recorded in terms of percentage.

The canola oil content was measured by NMR device that worked based on the magnetic induction of hydrogen nuclei and was a spectrum method. The advantage of this method is being nondestructive, and measures the oil content of the seeds the fast and accurately. The product of grain yield (kg/ha) to the

grain oil content (%), the grain oil yield was determined in kilograms per hectare. From the seeds of each plot, the amount of 150 g was transferred to the laboratory and the oleic acid, erucic acid and glucosinolate was measured using HPLC, and was recorded.
The analysis of the data was performed by using of statistical models in split plot design on a randomized complete block design and to compare the means the Duncan test was used and all of the statistical analysis was done using MSTATC software.

RESULTS AND DISCUSSION

According to the analysis of variance there were significant differences between different irrigation regimes for all traits in the probability level of 1% i.e. the different treatments of moisture content were effective on the measured traits. The effect of different cultivars was significant on all of the traits except; the plant height, stem diameter, and the number of branches per plant. The interaction between cultivar and irrigation regimes was significant on the stem diameter and the number of pods per plant ($p \leq 0.01$) and the plant height, the number of branches per plant, and the number of seeds per pods ($p \leq 0.05$) (Table 2).

Plant Height

The treatment of cut irrigation after stem elongation stage (I-2) had significantly the least plant height compared to other treatments. The results showed that the cutting irrigation in the primary stages of the growth had a large effect on plant height and resulted to plant height reduction due to less number of nodes and shorter internode distance (Table 3). Ghobady *et al.*, also reported the plant height reduction resulted by the drought stress.
Accordingly, it could be estimated that the autumn rapeseed could use the proper moisture of the fall, winter and spring to have a suitable vegetative growth while the most of rainfall in the country occurred in these seasons (Alyary *et al.*, 2000).

Stem Diameter

The ANOVA revealed that there was a significant difference between the irrigation regimes and the interaction between irrigation regimes and the cultivar for the stem diameter in probability level of 1% while the cultivar treatment had no significant effect (Table 2). According to the table 3, the mean comparison showed that the most average of stem diameter was related to L5 cultivar (18.6 mm) in control treatment (I-0) and the least was occurred in L5 (10.1) in the treatment of cut irrigation after stem elongation (I-1). The differences might relate to the genetic potential of the cultivar.

The Number of Branches per Plant

The effect if irrigation regimes and the interactions between irrigation and cultivar were significant on the number of branches per plant at the probability level of 1% and 5%, respectively (Table 2).
The mean comparison showed that for the number of branches per plant the most branches were occurred in SW101 with average of 8.3 and the least was occurred in L5 with average of 3.1 (Table 3).

The Number of Pods per Plant

The effect of irrigation regimes, cultivars, and the interaction between them were significant on the number of pods per plant at probability levels of 1% (Table 2). The mean comparison of this trait showed that the most number of pods per plant was in SW101 (157.5) at I-0 condition and the least one was in L5 (36) at I-1 condition. Mainly the water at flowering stage stress resulted to loss of flowers and developing pods due to less supply of photosynthesis materials under the stress during this period. These results were in line with the researches of Singh and Kumar (1998).

The Number of Seeds per Pod

The number of seeds per canola pod has a capacity of close to 30 ovules at flowering stage, but the final number is always less than the mentioned amount. Researchers reported the supply constraints of photosynthetic materials and other environmental factors were effective on the number of seeds per pod (Mendham & Salisbury, 1995).
The ANOVA showed that the effect of irrigation regimes was significant on the number of seeds per pod at probability level of 1% while the effect of cultivars was not significant and the effect of interaction of

cultivar and irrigation regimes was significant at probability level of 5% (Table 2). The mean comparison showed that the average of most number of seeds per pods was 25.2 in SW101 at I-0 and the least was occurred at I-1 condition for L5 with the average of 11.5 (Table 3).
It seems that the water shortage reduced the absorption of photosynthetic materials and this caused a loss in the number of seeds per pod. Other reports were provided about the negative impacts of drought stress on the seed number per pod (Sinaki *et al.*, 2007).

Table 2: Analysis of variance for plant height, stem diameter, number of branches per plant, number of pods per plant and number of seeds per pod for different cultivars of rapeseed

Variables	df	Mean of squares				
		Plant height	Stem diameter	Number of branches per plant	Number of pods per plant	Number of seeds per pod
Replication	2	37/77 ns	1/63 ns	0/791 ns	84/538 ns	1/882 ns
Irrigation regime	3	19966/195**	176/681**	62/603**	31004/936**	325/984**
error	6	58/127	1/539	0/187	33/427	1/173
cultivar	5	176/195 ns	0/628 ns	0/171 ns	168/304 **	2/051 ns
Irrigation*cultivar	15	289/633 *	2/192 **	0/93 *	388/612 **	6/094 *
error	40	115/603	0/599	0/404	17/274	2/48
CV (%)	-	12/65	10/44	11/25	12/72	8/73

*ns: non-significant, *: significant at the 5%, ** significant at the probability level of 1%.*

Thousand Seeds Weight

Final grain weight is a function of the growth rate and duration of grain filling (Ney & Turc, 1994). The amount of thousand seeds weight represents the seed development and is an important factor determining the yield potential of rapeseed (Sadaqat *et al.*, 2003). Analysis of variance for 1000-seed weight indicated that a significant difference was observed in 5% probability level between the repetitions. As shown in Table 4, there was a significant difference between different irrigation regimes for all traits at probability level of 1%. Also the effect of interaction between irrigation regimes and cultivars was significant on the 1000-seed weight at probability level of 5% (Table 4).
The results of the mean comparison indicated that the most 1000-seed weight was observed in I-0 treatment related to SW101 cultivar (4.9 g) and the least was belonged to I-2 treatment for HW113 cultivar with the average of 2.1 g (Table 5).
The decrease in 1000-seed weight following the cessation of irrigation was possibly due to reduce in production and transportation of the photosynthesis materials into the grain. It seemed that the plant could not even compensate the decrease in the assimilation due to drought stress by retranslocation of its accumulated reserves. Daneshmand *et al.*, (2006) also reported the same results in this case.

Grain Yield

Between different regimes of moisture and grain yield a significant difference was observed in the probability of level 1%. There was no significant difference in grain yield between varieties and the effect of interaction between cultivar and irrigation regimes was significant on the grain yield at probability level of 5% (Table 4).
The most average of grain yield was observed in SW101 cultivar (5315 kg/ha) at I-0 and the least was in L5 cultivar (1897 kg/ha) at I-1 (Table 5).

Table 3: The mean comparison of plant height, stem diameter, number of branches per plant, number of pods per plant and the number of seed per pod for cultivars of rapeseed

Irrigation	Cultivar	Average plant height (cm)	stem diameter (mm)	number of branches per plant	number of pods per plant	number of seed per pod
Common irrigation (Control, I-0)	HW113	$161/8^{abc}$	$18/2^{abc}$	$7/9^{abc}$	$146/3^{b}$	$23/5^{abc}$
	KR4	$146/7^{b-f}$	$17/1^{cde}$	$7/4^{a-d}$	$122/2^{d}$	$21/5^{b-e}$
	HW101	$158/7^{a-d}$	$17/7^{a-d}$	$7/7^{abc}$	$140/4^{b}$	$23/1^{abc}$
	SW101	$171/6^{a}$	$18/9^{a}$	$8/3^{a}$	$157/5^{a}$	$25/2^{a}$
	L5	$165/3^{ab}$	$18/6^{ab}$	$8/1^{ab}$	$54/4^{a}$	$23/8^{ab}$
	HW118	$152/3^{a-e}$	$17/3^{b-e}$	$7/6^{abc}$	$130/5^{a}$	22^{bcd}
cut irrigation after stem elongation stage (I-1)	HW113	$91/2^{klm}$	$11/1^{m-p}$	$3/8^{l-o}$	$50/8^{no}$	$14/1^{m-q}$
	KR4	$75/9^{mn}$	$10/5^{op}$	$3/5^{no}$	$44/9^{op}$	$12/9^{opq}$
	HW101	$99/6^{jkl}$	$11/4^{m-p}$	$3/9^{l-o}$	$54/6^{mn}$	$14/7^{l-p}$
	SW101	$83/7^{lmn}$	$10/8^{nop}$	$3/7^{mno}$	47^{o}	$13/3^{n-p}$
	L5	$64/8^{n}$	$10/1^{p}$	$3/1^{o}$	36^{q}	$11/5^{q}$
	HW118	$70/4^{n}$	$10/3^{op}$	$3/3^{o}$	$38/6^{pq}$	$12/4^{pq}$
cut irrigation after the flowering stage (I-2)	HW113	$118/2^{hij}$	$12/5^{klm}$	$4/8^{i-m}$	$67/6^{l}$	$16/2^{i-n}$
	KR4	$127/7^{f-j}$	$14/2^{hil}$	$5/5^{g-j}$	$80/1^{ij}$	$17/4^{g-k}$
	HW101	$125/3^{ghi}$	$13/7^{ijk}$	$5/1^{h-k}$	$75/8^{jk}$	17^{h-m}
	SW101	$112/4^{ij}$	$12/2^{lmn}$	$4/5^{j-n}$	$60/5^{m}$	$15/7^{j-o}$
	L5	$108/7^{ijk}$	$11/7^{mno}$	$4/1^{k-o}$	$56/5^{mn}$	$15/4^{k-o}$
	HW118	$120/6^{hi}$	$13/1^{jkl}$	$4/9^{i-l}$	$71/4^{kl}$	$16/8^{i-m}$
cut irrigation after the podding development stage (I-3)	HW113	$135/3^{e-h}$	$14/8^{ghi}$	$6/3^{d-g}$	$92/6^{g}$	19^{e-i}
	KR4	$141/4^{d-g}$	$15/5^{fgh}$	$6/4^{d-g}$	$94/6^{g}$	$19/8^{d-h}$
	HW101	$128/9^{f-i}$	$14/5^{hi}$	$5/7^{f-i}$	$83/4^{hi}$	18^{f-k}
	SW101	$143/8^{c-g}$	$16/1^{efg}$	$6/8^{c-f}$	106^{f}	$20/2^{d-g}$
	L5	$145/2^{c-g}$	$16/6^{def}$	$7/1^{b-e}$	113^{e}	$20/6^{c-f}$
	HW118	$132/8^{e-h}$	$14/6^{hi}$	$6/1^{e-h}$	$87/8^{gh}$	$18/4^{f-j}$

In each column, means with different letters are significantly different, according to ANOVA and the Duncan's test in probability level of 5%.

Biological Yield

The ANOVA for the biologic yield indicated that significant difference was observed between the different regimes of water ($p \leq 0.01$) and the interaction between cultivars and irrigation regimes ($p \leq 0.05$) ,while there was no significant difference between cultivars (Table 4).

The SW101 cultivar with the average biological yield of 19150 kg/ha at I-0 treatment and the L5 cultivar with the average of 8146 kg/ha at I-1 treatment had the most and the least biological yield according to mean comparison (Table 5).

Harvest Index

There were several studies on the significant effects of the drought stress on harvest index for different crops such as; sunflower (Saffary, 2006) and safflower (Nadery *et al.*, 2005). However, only the interaction between the cultivar and irrigation regimes was significant ($p \leq 0.05$) (Table 4).

The most harvest index, according to mean comparison, was occurred in HW101 at I-0 treatment with the average of 29.14% and the least was in L5 at I-2 treatment (Table 5). Cut irrigation in the early stages of plant growth could lead to less vegetative and reproductive growth and so reduced plant height, number of pods and number of seeds per pod. Drought stress at flowering and pods development stages of the plant growth had fewer effects on yield because the plant had almost completed its vegetative growth and metabolic reduction reduced the yield components and biological yield.

Table 4: Analysis of variance of 1000-seed weight, biological yield, grain yield and harvest index for different cultivars of Rapeseed

Variables	df	Mean of squares 1000-seed weight (g)	Biological yield (kg/ha)	Grain yield (kg/ha)	Harvest index (%)
Replication	2	1/08 *	6204470/375 ns	21938/292 ns	34/44 ns
Irrigation regime	3	14/75**	265359837/125**	25634794/333**	32/734 ns
error	6	0/147	2754144/819	168621/625	30/508
cultivar	5	0/101 ns	729224/825 ns	146432/3 ns	6/45 ns
Irrigation*cultivar	15	0/967 *	5777176/425 *	721934/233 *	45/195 *
error	40	0/648	2104988/908	257179/942	21/493
CV (%)	-	12/16	10/48	13/92	17/66

*ns: non-significant, *: significant at the 5%, ** significant at the probability level of 1%.*

Table 5: Comparison of mean 1000-seed weight, biological yield, grain yield and harvest index for Cultivars of rapeseed plant

Irrigation	Cultivar	Average 1000-seed weight (g)	Biological yield (kg/ha)	Grain yield (kg/ha)	Harvest index (%)
Common irrigation (Control, I-0)	HW113	4/7 abc	18260 ab	5243 a	28/81 a
	KR4	4/4 a-e	17130 a-d	4514 abc	26/28 ab
	HW101	4/6 a-d	17940 abc	5242 a	29/14 a
	SW101	4/9 a	19150 a	5315 a	27/9 a
	L5	4/8 ab	18880 a	5303 a	28/13 a
	HW118	4/5 a-d	17640 abc	4798 ab	27/34 a
cut irrigation after stem elongation stage (I-1)	HW113	2/1 i	10130 lmn	2351 hi	24/27 b
	KR4	2/6 ghi	8642 n	2282 hi	26/37 ab
	HW101	2/9 e-i	10800 k-n	2731 f-i	24/98 b
	SW101	2/7 f-i	9085 mn	2291 hi	25/09 b
	L5	2/4 hi	8146 n	1897 i	23/4 b
	HW118	2/5 hi	8458 n	2240 hi	26/61 ab
cut irrigation after the flowering stage (I-2)	HW113	3/3 b-i	12480 i-l	3203 e-h	26/53 ab
	KR4	3/6 a-i	13640 f-j	3656 c-f	27/37 a
	HW101	3/5 a-i	13160 g-k	3362 d-g	25/68 b
	SW101	3/2 c-i	11760 jkl	2786 f-i	23/79 b
	L5	3/1 d-i	11650 j-m	2521 ghi	21/93 c
	HW118	3/4 a-i	12730 h-l	3300 d-g	25/96 ab
cut irrigation after the podding development stage (I-3)	HW113	3/9 a-h	15260 c-h	3985 b-e	26/14 ab
	KR4	4/1 a-g	15750 b-g	3996 b-e	25/79 ab
	HW101	3/7 a-h	14130 e-j	3949 b-e	28/12 a
	SW101	4/2 a-f	16120 b-f	4201 bcd	27/33 a
	L5	4/3 a-e	16450 a-e	4262 bcd	26/19 ab
	HW118	3/8 a-h	14760 d-i	3984 b-e	27/04 a

In each column, means with different letters are significantly different, according to ANOVA and the Duncan's test in probability level of 5%.

Seed Oil Percentage

The analysis of variance showed that significant differences were observed in the probability level of 1% for the trait of the seed oil percentage between different moisture regimes and interaction between cultivars and different irrigation regimes (Table 6).

The results of mean comparison showed that the highest and lowest percentage of oil were observed at the control of the SW101 (25/45%) and I-1 of L5 (41.37%), respectively (Table 7). Slight differences in the percentage of oil were likely due to genetic varieties between cultivars.

The Seed Oil Yield

The seed oil yield depends on two factors of the grain yield and the seed oil percentage, decrease or increase in any of these factors will cause changes in oil yield. The ANOVA for the seed oil yield trait revealed that the effects of irrigation regimes ($p \leq 0.01$), cultivars ($p \leq 0.05$), and the interaction between them ($p \leq 0.01$) were significant (Table 6).

As it is shown in table 7, the most oil yield was in SW101 cultivar with the average of 2407 kg/ha at control treatment and the least was in L5 cultivar with the average of 784 kg/ha at I-2 treatment. Given that the amount of oil and the grain yield reduced under drought stress, so the oil yield also declined. Ghobady *et al.*, (2006) reported the effects of water deficit stress on reduction of seed oil yield.

The Glucosinolate Content

According to the analysis of variance the difference between irrigation regimes was significant at probability level of 1% for the glucosinolate trait. There was no significant difference between the cultivars for the glucosinolate content i.e. the glucosinolate content had no dramatic differences between cultivars. The effect of interaction between cultivars and irrigation regimes was significant on glucosinolate content at the probability level of 5% (Table 6).

According to mean comparison, the highest amount of glucosinolate was occurred in L5 cultivar at I-1 treatment (29.25 mg/g meal dry weight) and the lowest was observed in SW101 cultivar at I-0 treatment (20.17 mg/g meal dry weight) (Table 7).

The Erucic Acid Content

The ANOVA indicated that there was a significant difference between irrigation regimes for the erucic acid content at probability level of 1% but the effect of cultivars was not significant. The effect of interaction between irrigation regimes and cultivar was significant ($p \leq 0.05$) for the erucic acid content (Table 6).

The highest and the lowest amount of the erucic acid content were in L5 cultivar at I-1 treatment (0.1998%) and SW101 cultivar at I-0 treatment (0.1456%), respectively (Table 7).

The Oleic Acid Content

The effect of different irrigation regimes was significant on the percentage of oleic acid at probability level of 1%. There was no significant difference between different cultivars for the oleic acid content while the interaction between cultivars and irrigation regimes was significant at probability level of 5% (Table 6). The results of mean comparison showed that the highest amount of oleic acid content was occurred in L5 at I-0 treatment with the average of 63.85% and the lowest amount was in L5 cultivar at I-1 treatment with the average of 61.12% (Table 7).

Table 6: Analysis of variance of the seed oil percentage, seed oil yield, erucic acid, oleic acid and glucosinolate for cultivars of rapeseed

Variables	**df**	**Mean of squares**				
		seed oil percentage	**seed oil yield**	**Erucic acid**	**Oleic acid**	**Glucosinolate**
Replication	2	0/098 ns	5969/847 ns	0/275 ns	0/501 ns	2/899 **
Irrigation regime	3	26/756**	5648566/162**	48/153**	14/887**	193/844**
error	6	0/048	31859/106	1/151	0/162	0/097
cultivar	5	0/313 *	25209/114 ns	0/512 ns	0/169 ns	1/516 ns
Irrigation*cultivar	15	0/422 **	92452/529 *	4/768 *	0/634 *	2/499 *
error	40	0/125	50741/258	2/312	0/185	0/822
CV (%)		4/82	14/27	9/11	4/69	3/48

*ns: non-significant, *: significant at the 5%, ** significant at the probability level of 1%.*

Table 7: The mean comparison of the seed oil percentage, seed oil yield, erucic acid content, oleic acid and glucosinolate content for different rapeseed cultivars

Irrigation	Cultivar	Average				
		seed oil percentage	**seed oil yield (kg/ha)**	**Erucic acid (%)**	**Oleic acid (%)**	**Glucosinolate (mg/g meal dry weight)**
Common irrigation (Control, I-0)	HW113	44/72^{ab}	2344^{ab}	0/1487de	63/62^{abc}	21/78^{kl}
	KR4	43/96^{cd}	1986^{bcd}	0/1543^{def}	62/99^{c-f}	23/25^{ijk}
	HW101	44/31^{bc}	2323^{ab}	0/1521^{def}	63/35^{bcd}	22/33^{k}
	SW101	45/25^{a}	2407^{a}	0/1456^{f}	64/13^{a}	20/17^{m}
	L5	45/16^{a}	2395^{ab}	0/1482^{ef}	63/85^{ab}	20/42^{lm}
	HW118	44/12^{bc}	2118^{abc}	0/1535^{def}	63/18^{b-e}	22/77^{jk}
cut irrigation after stem elongation stage (I-1)	HW113	41/78^{jkl}	981^{jk}	0/1821^{a-d}	61/48^{kl}	28/99^{ab}
	KR4	41/66^{kl}	951^{jk}	0/1897^{ab}	61/38^{kl}	29/11^{ab}
	HW101	42/22^{ijk}	1155^{h-k}	0/1785^{a-e}	61/77^{jkl}	28/97^{ab}
	SW101	41/73^{jkl}	957^{jk}	0/1872^{abc}	61/44^{kl}	28/99^{ab}
	L5	41/37^{l}	784^{k}	0/1998^{a}	61/12^{l}	29/25^{a}
	HW118	41/52^{l}	930^{jk}	0/1912^{ab}	61/22^{l}	29/12^{ab}
cut irrigation after the flowering stage (I-2)	HW113	42/43^{i}	1359^{g-j}	0/1717^{a-f}	61/88^{i-l}	28/34^{abc}
	KR4	42/71^{ghi}	1562^{d-h}	0/1636^{b-f}	62/13^{g-k}	27/15^{cde}
	HW101	42/66^{ghi}	1434^{e-i}	0/1685^{b-f}	62/11^{g-k}	27/46^{b-e}
	SW101	42/37^{ij}	1181^{h-k}	0/1728^{a-f}	61/86^{i-l}	28/83^{ab}
	L5	42/31^{ij}	1067^{ijk}	0/1762^{a-e}	61/82^{i-l}	28/95^{ab}
	HW118	42/55^{hi}	1404^{f-i}	0/1695^{b-f}	61/91^{h-l}	28/12^{a-d}
cut irrigation after the podding development stage (I-3)	HW113	43/11^{e-h}	1718^{c-g}	0/1586^{c-f}	62/55^{d-j}	25/25^{fgh}
	KR4	43/22^{efg}	1727^{c-g}	0/1572^{def}	62/62^{d-i}	24/88^{ghi}
	HW101	42/82^{ghi}	1691^{c-g}	0/1622^{b-f}	62/34^{f-j}	26/56^{def}
	SW101	43/48^{def}	1827^{c-f}	0/1561^{def}	62/72^{d-h}	24/51^{hi}
	L5	43/72^{cde}	1863^{cde}	0/1555^{def}	62/89^{c-g}	24/15^{hij}
	HW118	42/87^{f-i}	1708^{c-g}	0/1618^{b-f}	62/47^{e-j}	26/14^{efg}

In each column, means with different letters are significantly different, according to ANOVA and the Duncan's test in probability level of 5%.

Conclusion

The overall results of the research indicated that some traits like the high number of seeds per pods and high 1000-seed weight could have an effective role on the suitable grain yield in shortage of water. According to the results obtained in this research, the most sensitive stages of plant growth were the stem elongation, flowering and first of pods development stages at drought stress condition. Cut irrigation at flowering stage decreased the number of pods per plant due to fail and fall of flowers. At the stem elongation stage that the meristem reproductive organs were formed, if the plant exposed to water deficit stress the flower would decrease the production potential and so the number of pods and total seed number and ultimately, the grain yield and seed oil yield would decrease. In terms of physiologic, the

drought stress decreased dry matter production and storage in the vegetative organs during stem elongation stage then on retranslocation it to the reproductive organs would reduce the final yield.
The results indicated that the that the HW101 cultivar could be used as a suitable cultivar at regions with moisture limitation especially in stem elongation stage and the KR4 could be utilized as a proper cultivar at regions with drought stress in flowering stage and the L5 could be used in areas where might face the drought stress at the end of the planting season, so, rapeseed cultivation could be extended in the dry areas.

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