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ORIGINAL ARTICLE

The Effects of Drought Stress on Seed yield and Some Agronomic Traits of Canola cultivars at Different Growth stages

Amir Mirzaei[1], *Rahim Naseri[2], Ali Moghadam[3] and Mohammad Esmailpour-Jahromi[4]
[1]Department of Agronomy, Faculty of Agriculture and Natural Resources, Islamic Azad University, Karaj Branch, Karaj, Iran
[2]Young Researchers and Elite Club, Ilam Branch, Islamic Azad University, Ilam, Iran
[3]Department of Agriculture, Pyame Noor University. PO.BOX 19395-4697. Tehran. I.R. of Iran
[4]Department of Horticulture, Jahrom University, 74137-66171, Jahrom, Iran
*Corresponding author: rahim.naseri@gmail.com

ABSTRACT
An experiment was conducted as split plot arrangement in a randomized complete block design (RCBD) with three replications to study the effect of drought stress at different growth stages on qualitative and quantitative traits and some agronomic traits of four canola cultivars, in western Iran during 2008-2009 and 2009-2010 growing season. Main plots included four drought stress levels (Full irrigation, stress at flowering, pod developing and seed forming stages) and subplots included four cultivars (Hyola401, Hyola308, Zarfam and PF). The results indicated that drought stress treatments had significant affect on seed yield, number of seeds.pod^{-1}, number pod per plant, number of branches per plant, 1000-seed weight, plant height and oil content. In this experiment, stress at flowering stage had the most effect on pod number per plant, number of seeds per pod, number of branches per plant and plant height. Seed forming stage was the most sensitive stage, so that 1000-seed weight and oil content were decreased in this stage. The highest (3151.25 kg.ha^{-1}) and lowest (2377.08 kg.ha^{-1}) seed yield belonged to full irrigation and stress at flowering stage, respectively. Cultivar factors had significant effect on seed yield, yield components, number of branches per plant, plant height and oil content. The highest (2925 kg. ha^{-1}) and lowest (2523.7 kg.ha^{-1}) seed yield belonged to Hyola401 and Zarfam, respectively. Interaction effects of drought stress×cultivar had an effect on seed yield, yield components and hadn't significant effect on other traits. Also, results of this experiment indicated that stress at flowering stage is more sensitive to water deficit due to pod number per plant and number of seeds per pod. So, Hyola401 cultivar is recommended due to having higher seed yield and yield components in western Iran.
Keywords: *Drought stress; Canola; Seed yield and yield components.*

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INTRODUCTION

Canola (Brassica napus L.) is one of the oil seed crops wich is cultivated in Iran [1] containing 40 to 45 oil percentage. Canola oil has 61% oleic acid and 8.8% linoleic acid and as compared with other oil seeds have better quality. Plant area of canola (Brassica napus L.) has increased from 34,000 ha to 145,000 ha in Iran and its production has increased from 43,000 tons in 2000-2001 to 180,000 tons, in 2006-2007 [2]. Water stress affected significantly the pod numbers per plant and the number of seeds per pod [3]. Water stress is the most limitating factor for canola production in semi-arid regions of the world [3]. Therefore, the development of new canola cultivars with high efficiency and ability to drought resistance is very important. Quality of water and soil properties is being reduced for canola production. [4]. Pod numbers per plant, seed and oil yield of canola is decreased by water stress [5]. High seed yield with an increase of irrigation number has been reported by Hati *et al.*, [6] and Maleki *et al.*, [7]. Irrigation can increase seed yield of canola from 41.7% to 62.9% as compared to unirrigated treatments [8].

Physiological processes such as photosynthesis, cell turgidity and cells growth are highly affected by water stress [9]. Photosynthesis decreases [10] under drought stress conditions. Higher electron leakage in photosynthetic and respiratory processes in drought stress induced oxidative stress in the plant cell. Enhance of the reactive oxygen species (ROS) generation takes place [11]. Gumasekara *et al.*, [12] reported the grain yield reduction of brassica napus, and brasssica juncea due to drought stress. Seed yield reduction occurred by low water availability during stem elongation, flowering and pod development with caused reduction of pod per plant. Supplemental irrigation applied at grain-filling stage

increased the grain yield [13]. Hang *et al*., [14] indicated that irrigation during stem elongation, increased grain yield in non-irrigation conditions. Guttieri *et al*., [15] and Zhang *et al*., [16] reported that drought stress reduced grain yield caused by low kernel growth rate, whereas Altenbach *et al.,* [17] found that grain filling shortening caused kernel size and yield reductions. The aim of this study was to determine the effect of drought stress at different growth stages on qualitative and quantities traits of four canola cultivars**.**

MATERIAL AND METHOD

Experiment was conducted as split plot design on a randomized complete block design (RCBD) with three replications in Mehran, Iran (with coordinates of 33○ 7′ N and 46○ 10′ E) during 2008-2009 and 2009-2010 growing season. Main plots included four drought stress levels (full irrigation, water stress at flowering, pod formation and seed development stages) where as subplot included four cultivars (Hyola401, Hyola308, Zarfam and PF). Soil texture was loam at 30 cm depth, EC and pH were 0.62 $ds.m^{-1}$ and 7.32, respectively. Canola seeds were planted by hand in 5 m long and 2 m width plots at 3 cm depth. For all treatments ammonium phosphate fertilizer was applied at 50 and 150 $kg.ha^{-1}$, respectively. Other two-third of N-Urea (175 $kg.ha^{-1}$) was split equally at the beginning of the stem elongation and flowering. Weeds were controled from plots close to physiological maturity plants; plots were harvested (eliminating edges) and sent to the laboratory to determining seed yield and yield components. 10 plants were selected randomly to measure the plant height and number of branches per plant. Oil seed contents were measured by using Magnetic Nuclear Resonance Spectrophotometer (NMR). Data analysis of variance was conducted using MSTATC software. Mean comparison was conducted using the Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

*Number pods per plant***:**

A significant difference in pods number per plant was observed during the two seasons 2008-2009 and 2009-2010, so the highest (77 pods per plant) number of pods were obtained in the second year (Table 1).

Table 1. Analysis of variance of agronomic traits of canola in 2008-2009 and 2009-2010 growing season

		Ms						
S.O.V	df	Pod number per plant	Seed number per pod	1000-seed weight	Seed yield	Number of branches per plant	Plant height	Oil percent
Year (Y)	1	2981.5	159.13	1.68	4973151.04	864	2926.04	184.53
Y/R	4	199.9^{ns}	19.3^{*}	0.1^{ns}	305511.45^{ns}	5.18^{ns}	57.9^{ns}	10.5^{ns}
Drought stress(DS)	3	3209.5^{**}	142.43^{**}	2.86^{**}	2416945.4^{**}	231.04^{**}	565.9^{*}	196.8^{**}
Y×DS	3	57.9^{ns}	0.192^{ns}	0.001^{ns}	384737.1^{ns}	0.33^{ns}	85.56^{ns}	2.07^{ns}
Error a	12	194.472	4.27	0.045	203064.23	1.854	95.597	6.3
Cultivar (C)	3	1912.7^{**}	104.01^{**}	1.91^{**}	658484.3^{**}	101.62^{**}	476.6^{**}	79.4^{**}
Y× C	3	120.14^{**}	0.314^{ns}	0.008^{ns}	26687.15^{ns}	0.750^{ns}	48.48^{ns}	2.7^{ns}
DS×C	9	60.2^{*}	4.4^{**}	0.085^{**}	75789.005^{*}	2.92^{ns}	98.3^{ns}	5.1^{ns}
Y× DS× C	9	30.5^{ns}	0.307^{ns}	0.002^{ns}	27954^{ns}	0.194^{ns}	39.7^{ns}	1.1^{ns}
Error b	48	22.62	1.26	0.021	28827.4	1.54	65.7	3.53
CV (%)		6.6	8.6	4.43	6.19	8.77	7.30	4.70

Ns, * and **: non-significant and Significant at 5 %and 1 %probability levels, respectively

Drought stress caused reducing these traits, the highest and lowest pods numbers per plant were observed in full irrigation and stress at flowering stage, respectively (Table 2). It is concluded that drought stress had most effect on non-inoculation flowers and their falling. So sever falling flowers and non-inoculation at stress condition was observed at flowering stage during experiment. It can be said based on obtained results that time of using drought stress comes nearer to flowering stage; its effect was increased on number of pods and finally the seed yield. Increasing irrigation water fertile flowers and finally growing pods and seed yield last long and leave become old shower, and as a results the number of pods per plant are increased and on the other hand decreasing irrigation water caused an early growth stages of plant. Mouhouche *et al*., [18] suggested that number of pods per plant have more sensitive effects on drought stress. Drought stress especially at pod formatting stage plays an important role for high yield and desired quality and it can gravely decrease the yield [19]. Wrigth *et al*., [20] also indicated that canola, sever reduction of dry matter of pod and it's numbers, resulted from more falling flowers and pods and this problem is more obvious at more severe stresses. Interaction effects drought stress and cultivar on number of pods per plant was significant at 5% probability level (Table 3).The highest pods per plant used full irrigation and Hyola401 cultivar and the lowest pods per plant used stress at

flowering stage and Zarfam cultivar (Table 4). Due attention to results indicated the seed yield of these cultivars, it concluded that one of the important causes of sustaining seed yield of these cultivars at deficit water stress condition in high ability to producing pods per plant. Also low number pods per plant of Zarfam cultivar at stress treatment at flowering stage can be a cause to decreasing seed yield of the cultivar in comparison with full irrigation treatment.Results of trait correlation Table also showed the same (Table 4).

*Number of seeds per pod***:**

Both years of 2008-2009 and 2009- 2010 had significant difference in number of seeds per pod, so the highest (14.2 seed) number of seeds per pod was observed in 209-2010. Reducing water at flowering stress stage resulted in decrease of this trait (Table 3).

Jones *et al*., [21] indicated a water deficit during flowering stage influenced significantly the number of seeds whereas deficit of water after pollinating reduced the seed size. These findings are supported by those of Rathore and Patel [22] who reported higher number of pods and number of seeds per pod at higher irrigation frequencies. It is obvious that at flowering stage during which the inoculation conducted, deficit moisture causes to inoculation don't conducted well had its result, is floret abortion. The Cause of seeds numbers reduction per pod during deficit water stress are decreasing number of flowers and lowering number flowers which converted to seed. On the one hand we know that transmitting materials from phloem depend on both photosynthesis which supply main materials and sink metabolism. Deficit water stress caused reducing of photosynthesis and consuming of photosynthesis matters by growing leaves, as a result the drought reducing indirectly the photosynthesis matters produced by leaves because extract transferring from phloem is dependent of pressure potential, during water stress, reducing turgor potential also decrease the phloem photosynthesis materials and finally assimilation amount which lead to increasing vulnerability of seed formatting under deficit water conditions. In this study, the cause of seeds decreasing number per pod under deficit water condition is that drought stress at reproductive growth stage caused to produce preserved extract, this state caused to aborting reproductive organs (flowers) and as a result increasing vulnerability of seed formatin in pods under drought stress condition. Interaction effects of drought stress and cultivar on number of seeds per pod was significant at1% probability level (Table 2). The highest seeds per pod used full irrigation and Hyola401 cultivar and the lowest seeds per pod used stress at flowering stage and Zarfam cultivar (Table 4). The high number of seeds per pod is a benefit and has well effect on increasing of seed yield. As traits correlation indicated, the seeds number per pod has positive and significant correlation with seed yield.

Table *2*. Mean comparisono of agronomic traits of canola in 2008-2009 and 2009-2010 growing seasons

Treatment	Pod number per plant	Seed number per pod	1000-seed weight (g)	Seed yield (kg. ha^{-1})	Number of branches per plant	Plant height (cm)	Oil percent (%)
Year							
2008-2009	65.8b	11.79b	3.1b	2515.20b	11.1b	105.4b	38.6b
2009-2010	77a	14.3a	3.4a	2970.4a	17.1a	116.5a	41.4a
Drought stress							
Full irrigation	82.5a	15.8a	3.59a	3151.25a	18.4a	116.5a	43.3a
Stress at flowering stage	55.1c	9.9c	3.37b	2377.08c	11.2c	105.4b	40.4b
Stress at pod developing stage	73.9b	13.6b	3.32b	2703.7b	12.6b	108.8ab	39.9b
Stress at seed formatting stage	74.08b	12.9b	2.77c	2739.1b	14.4b	113.08ab	36.3c
Cultivar							
Hyola401	82.2a	15.8a	3.58a	2925a	16.7a	117.04a	41.8a
Hyola308	73.2b	13.04b	3.36b	2746.2b	14.5b	109.7b	40.5b
Zarfam	60.7c	10.8c	2.91c	2523.7c	11.9c	106.3b	37.5c
PF	69.4b	12.5b	3.2b	2776.2b	13.6b	110.8ab	40.1b

Means in each column followed by similar letters are not significantly different at 5 %probability level, using Duncan's Multiple Rang Test

1000-seed weight:

Results indicated that a significant difference was observed in 1000-seed weight during two years of 2008-2009 and 2009-2010 (Table 2). Second year, 2009-2010 had a highest 1000-seed weight (3.49 g). Severe drought stress seed forming stage results in significant reduction of these traits (2.7 g). It must be defined that at seed formatting stage and at the end of growing period, all different parts of plant acted as sink and send all their stored photosynthesis matters to seed. This, any drought stress at this stage caused to fading, becoming small and thinning of the seeds. It also suggested that drought stress at seed formatting stage influenced mainly 1000-seed weight and resulted in decreasing of it [23]. In general, 1000-seed weight is influenced by their filling speed and duration .Environmental stresses such as deficit

stress especially at seed forming and filling decrease the seed filling speed and duration and finally its weight due to photosynthesis reduction. Pandy *et al*., [24] indicated that during water stress at flowering stage, the seed yield decreases due to reducing seeds weights. Deloche [25] showed that drought stress at seed filling stage caused to producing faded seeds. Keati and Cooper (*1998*) [26] suggested that decreasing seed weight under drought stress resulted from harmful effect of drought on producing biomass and drought stress caused to reducing seed weight. Poma *et al*., [27] also indicated in their study on effect of irrigation treatments on canola yield that all seed yield components decreased seed yield under drought condition. Interaction effects of the drought stress, and cultivar on 1000-seed weight was significant at5% probability level (Table 2). The highest 1000-seed weight uses full irrigation and Hyola401 cultivar and the lowest seeds per pod use stress at seed formatting stage and Zarfam cultivar (Table 4).

*The Seed yield and Number of seeds per pod***:**

The two years of 2008-2009 and 2009-2010 had significant seed yield. The highest seed yield was observed during 2009-2010 (2970.4 kg. ha^{-1}). Drought stress also decreased canola seeds yield. The highest and lowest seed yield was obtained at full irrigation and drought at flowering stage, respectively (Table 3). Positive and significant correlation between seed yield, number of pods per plant, number of seeds per pod and 1000-wight indicated that change of these traits caused the change in seed yield (Table 5). As a result the omission of any of these factors due to drought stress influences severely the seed yield. Flowering, pod formatting stages of canola plant are most sensitive stages to drought stress, this plant expose drought stress in most regions of Iran [4]. Results of Ma *et al*., [28] studies indicated that concurrency of reproductive stage during drought stress causes the reduce of most attributes related to canola yield such as number of pods per plant, number seeds per pod and 1000-sseed weight, reducing seed yield is mostly due to reducing number pods per plant, number of seeds per pod. Poma *et al*., [27] observed that all yield components were reduced in deficit water condition as seed yield. It seems that in this study, Hyola401 cultivar could yield more components to produced seed yield .The study showed that stress at different growth stages caused the decrease in seed yield, but stress at flowering stage had more effect on decreasing the yield. Interaction effects drought stress and cultivar on seed yield was significant at5% probability level (Table 2). The highest seed yield uses full irrigation and Hyola401 cultivar (Table 4). Hyola401 cultivar yields more seeds in other than under drought stress conditions. Enough rainfall during growth season and as a result providing water specially during spring (April) which was simultaneous with flowering period of all cultivars prevented the reproductive organs (flowers) abortion and bring them to nought and finally it caused to more pods numbers per plant, number of seeds per pod and 1000-seeds weight and finally higher seed yield in second year (Table 3).

Table *3*. Interaction of drought stress × canola cultivar on agronomic traits in 2008-2009 and 2009-2010 growing seasons

Treatment	Pod number per plant	Seed number per pod	1000-seed weight (g)	Seed yield (kg. ha^{-1})	Number of branches per plant	Plant height (cm)	Oil percent (%)
I_1 C_1	97.6a	20.2a	4.1a	3400a	22.3a	130.6a	45.5a
I_1 C_2	84.1bc	15.8bc	3.6b	3226.6a	18.3b	112.1bc	43.5ab
I_1 C_3	69.1fg	12.5def	3.1de	2848.3bcd	15.3cd	110.1bc	41.7bcd
I_1 C_4	79.1bcde	15.3bc	3.4bcd	3130ab	17.6b	113.3bc	42.9abc
I_2 C_1	65.1gh	12.2def	3.5b	2616.6cdef	13.3de	110.1bc	41.6bcd
I_2 C_2	59.1hi	9.5gh	3.4bc	2475ef	12.1ef	107.3bc	40.5bcde
I_2 C_3	40.6j	8.5h	3.03ef	2046.6g	9.1g	97.6c	39.3cde
I_2 C_4	55.6i	9.4gh	3.3bcd	2370f	10.3fg	106.6bc	40.2bcde
I_3 C_1	81.6bcd	15.6b	3.5b	2766.6cde	14.6cd	111.5bc	41.6bcd
I_3 C_2	75.8cdef	14.1bcd	3.4bc	2575def	13.3de	107.5bc	40.9bcd
I_3 C_3	66.5gh	11.7ef	3.03ef	2633.3cdef	10.3fg	106.8bc	37.1e
I_3 C_4	71.6efg	12.8de	3.2cde	2840bcd	12.3ef	109.6bc	40.1bcde
I_4 C_1	84.6b	15.2bc	3.03ef	2916.6bc	16.6bc	115.8b	38.6de
I_4 C_2	73.6defg	13.3e	2.9fg	2708.3cde	14.3de	111.8bc	37.3e
I_4 C_3	66.6gh	10.7fg	2.4h	2566.6cde	12.3ef	110.8c	32.3f
I_4 C_4	71.3efg	12.4def	2.7g	2765def	14.3de	113.8b	37.2e

Means in each column followed by similar letters are not significantly different at 5 %probability level, using Duncan's Multiple Rang Test

I_1, I_2, I_3 and I_4 = Full irrigation, Stress at flowering, Pod developing and Seed formatting stages, respectively.

C_1, C_2, C_3 and C4= Hyola401, Hyola308, Zarfam and PF cultivar, respectively.

Interaction effects drought stress and cultivar on seed yield was significant at 5% probability level (Table 2). Cultivars had different response at different levels drought stress on seed yield, so Hyolla401 cultivar

had highest seed yield using full irrigation at flowering stage and lowest seed yield obtained at flowering stag at Zarfam cultivar. High seed yield in Hyola401 cultivar can attribute to high numbers of pods per plant, number of seeds per pod and 1000-seeds weight.

But as showed in interaction effects comparison table, it caused a low seed yield of Zarfam cultrivar at low yield components (Table 4). Maliwal *et al*., [29] and Patel [30] have reported the reduced yield in Brassica (canola) in response to water stress.

Oil content:

The Results of study indicated that the two years had different oil content. The highest oil content was observed during second year. The experiment showed that oil content was decreased during deficit water stress from stage to physiological care [31].

Drought stress reduced the oil contents at high temperature. Co_2 would reduce the closing stomata and deficit effect of drought on photosynthesis system. On of the other hand, the plant growth duration was decreased under drought stress condition, enough time isn't available to crude protein, carbohydrates and therefore oil content of seed was decreased under these conditions. In this study it is observed that more and enough rainfall during growth period in second year caused increasing of net photosynthesis of cultivars and improving of stored carbohydrates (sugar). On of the other hand more time was available to crude protein and carbohydrates (sugar) due to increasing growth period duration cultivars in second year and oil content showed increasing under these conditions. These results are in agreement with the findings of Rahnema and Bakhshandeh [5].

Plant height:

A significant difference was observed in plant height between both said years. The highest plant yield was observed in the second year. Increasing drought stress resulted in reducing of plant height. These results were similar with the findings of Mesbah [32]. Decreasing plant height due to drought stress is one of the most prominent signals. It is defined that drought stress caused a height decrease by decreasing the plant growth and nears time to final stage of growth, drought stress have less effect on plant height (Table 3). It seems that more plant height under drought stress caused a decrease in seed yield. These findings are in agreement with the observations of Rathore and Patel [22].

Number of branches per plant:

A significant difference was observed in the number of branches per plant in both years. Increasing drought stress was resulted in significant decrease in branch numbers. A significant difference was also observed between irrigation treatments. Full irrigation and stress at flowering stage, the highest and lowest number of branches per plant, respectively (Table 3). This result is in agreement with Tahir *et al*., [9]. Among the experimented cultivars, Hyola401 cultivar had the highest number of branches and Zarfam cultivar had the lowest number of branches. Hyola 308 and PF cultivar hadn't significant difference and were present in the same group (Table 3). The results are supported by the findings of Rathore and Patel [22].

Table 4. Correlation coefficients between agronomic traits of canola in 2003-2004 and 2004-2005 growing seasons

Treatment	Pod number per plant	Seed number per pod	1000-seed weight	Seed yield	Number of branches per plant	Plant height	Oil percent
Number pods per plant	1						
Number seeds per pod	0.82**	1					
1000-seed weight	0.46**	0.55**	1				
Seed yield	0.75**	0.71**	0.46**	1			
Number of branches per plant	0.78**	0.78**	0.57**	0.77**	1		
Plant height	0.73**	0.72**	0.43**	0.61**	0.75**	1	
Oil percent	0.42**	0.54**	0.79**	0.53**	0.57**	0.40**	1

**: Significant at 1 % probability levels, respectively

CONCLUSIONS

Drought stress seed yield, yield components as well as the oil contents were studied in this study. By noticing the positive and efficient correlation of oil content and seed yield, it seems that the oil contents reduction leads to decrease of seed yield under drought stress condition. Hyola401 cultivar had the more seed yield and oil content at normal and drought stress conditions. Interaction effects of drought stress cultivar had an effect on seed yield as well as yield components. Also, the results of this experiment indicated that stress at flowering stage is more sensitive to water deficit due to pod numbers per plant and number of seeds per pod. Hyola401 cultivar is recommended due to having higher seed yield and yield components in western Iran.

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