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Effects of end-season drought stress on yield and yield components of rapeseed (*Brassica napus* L.) in warm regions of Kermanshah Province

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Abstract. In order to identify drought stress tolerance in 10 rapeseed (*Brassica napus* L.) varieties (Hyola42, Hyola308, Hyola420, Hyola401, Option 500, RGS003, RGS006, Sarigol, Amica and Kimberly) were evaluated under two conditions (irrigated and drought stress) in Sarpol-e-Zahab region in 2013-2014 growing season. Under drought stress conditions, irrigation was cut from flowering stage. Combined analysis results showed that drought stress had significant effect on plant height, stem diameter, lateral shoot number, biological yield, flowering duration, days to maturity, pod per plant, seed per pod, 1000 seed weight, seed yield and harvest index. Seed yield average reduced from 3955.1 to 2800.96 kg/ha (29.18%) caused by drought stress. Meanwhile pod per plant reduced more than other traits (32.54%). Cultivars were significantly different for all traits except stem diameter, flowering duration, days to maturity. The cultivar × conditions interaction effects were not significant for any traits. Under normal conditions, the Hyola420, Hyola42 and Sarigol cultivars had the highest seed yield respectively. Under drought stress conditions, Sarigol cultivar had the highest seed yield. Regression analysis using backward method showed that stem diameter, biological yield, days to flowering end and oil percent entered to seed yield model and explained 57% of all data variations. Path analysis based on regression analysis results revealed that plant height, pod per plant, seed per pod and 1000 seed weight had the highest direct effect on seed yield. Cluster analysis results indicated that oilseed rape lines were divided to 3 groups under both conditions. Analysis of variance for drought indices showed significant differences between cultivars for MP, STI and GMP. With consideration of correlation between indices and yield under stress and non-stress, these drought indices were identified as the best indices for isolation and selection of drought tolerant cultivars.

Key words: Oilseed rape, drought stress, yield components, drought stress index.

Introduction

Rapeseed (*Brassica napus* L.) production in Mediterranean region is often limited by sub-optimal moisture conditions. This crop is a main oilseed crop in the agricultural systems of many arid and semiarid areas where its yield is often restricted by water deficit and high temperatures during the reproductive development. Seed yield can be mainly limited even by the relatively short period of soil moisture shortage during the reproductive growth (Chaghakaboodi et al. 2012a).

Irrigated rapeseed cultivation is currently expanding in rotation with winter cereals in Iran where its reproductive growth is frequently exposed to water deficit in many areas (Kahrizi & Allahvarand 2012).

In rapeseed, the effect of water stress on crop depends on genotype, intensity and duration of stress, weather conditions and developmental stages. The occurrence time is more vital than the water stress intensity. Seed yield potential of rapeseed crops depends on the events occurring prior to and during the flowering stage, while the reproductive period is most susceptible to stress. Severe stress decreases the duration of reproductive growth and stress during flowering or ripening stages results in large yield losses (Chaghakaboodi et al 2012b, Chaghakaboodi et al. 2012c).

Water stress occurring at any time during reproductive growth can result a strong change in seed yield. The most horrible time to experience water deficit on many grain crops is throughout stem elongation and flowering (Kakaei et al. 2010, Garavandi et al. 2011, Ahmadi et al. 2012, Zebarjadi et al. 2012).

Rapeseed stressed by drought at earlier growth stages exhibited recovery, whereas stressed during pod development rigorously reduced most of the yield and yield components. The highest rapeseed yield decrease was obtained when water deficit occurred at flowering and then at pod developmental stages (Kahrizi & Allahvarand 2012).

Rahnema & Bakhshande (2006) reported that the highest seed yield reduction occurred when irrigation was only once applied in spring. Muhammad Tahir et al. (2007) found that the highest seed yield was obtained with three times irrigation at early vegetative, flowering and seed formation. Henry & MacDonald (1978) showed that severe drought decreased oil and increased protein contents of rapeseed.

The objective of this experiment was to determine the influences of water deficit stress at reproductive growth stages on yield and yield components of rapeseed advanced lines in Sarpol-e-Zahab in the west of Iran.

Material and methods

In order to identify drought stress tolerance in 10 rapeseed (*B. napus*) cultivars (Hyola42, Hyola308, Hyola420, Hyola401, Option 500, RGS003, RGS006, Sarigol, Amica and Kimberly) were evaluated under two conditions (irrigated and drought stress) in Research Station Sarpol-e-Zahab region, Kermanshah Province, Iran in 2013-2014 growing season.

The Sarpol-e-Zahab (longitude: 45° 51′ 45" E, latitude: 34° 27′ 39" N, elevation: 570 m) climate is warm and temperate in Sarpol-e Zahab. Throughout the year there is little rainfall. According to Köppen and Geiger climate is classified as Csa. The average annual temperature in Sarpol-e Zahab is 19.7 °C. The average annual rainfall is 485 mm.

There is a high potential for expansion of rapeseed cultivation in these regions as a promising alternative crop for diversification and economical use of land and water resources.

The amount and type of fertilizers to be used were determined on the basis of soil test as follows: potash, phosphorus, and nitrogenous fertilizer were used, respectably. Fertilizer application included 150 kg/ha of superphosphate before planting and urea which equally applied at both stem elongation and before flowering time. Other stages of crop management were performed routinely.

Under drought stress conditions, irrigation was cut from flowering stage. Canola seeds were sown (40-60 plants/m^2) by hand in 5 m long and 2 m width plots at 3 cm depth. The lines distances were 30 cm. 5-6 kg/ha seed were sown for supply 40-60 plants/m^2. Weeds were controlled 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 randomly selected to measure the plant height and number of branches per plant.

The amount of water applied was to restore the water to field capacity. Field capacity and permanent wilting point were previously measured by pressure plate. The design was arranged based on randomized complete block with three replications.

Plant height, number of branches per plant, seeds per pod, pods per main branch, branches number per plant, pods per plant, 1000-seed weight seed, stem diameter, duration of flowering, pod length flowering date, physiological maturity date, biological yield, seed yield, harvest index and oil yields were recorded. All plots were harvested number of branches and pods per plant, seeds per pod, 1000-seed weight, and seed and oil yields were determined. Seed oil contents were determined by Soxhlet methods.

For additional statistical analysis such as regression, correlation, path and cluster analysis, these analyses were done.

In order to consider susceptibility or resistance ratio of genotypes to water stress and evaluated main criteria for segregate genotypes, some indices were used as below:

(1.) Stress Tolerance Index (STI) (Fernandez 1992)

$$STI = \left[\frac{Y_p}{\overline{Y_p}}\right] \times \left[\frac{Y_s}{\overline{Y_s}}\right] \times \left[\frac{\overline{Y_s}}{\overline{Y_p}}\right] = \frac{Y_p \times Y_s}{\left(\overline{Y_p}\right)^2}$$

(2.) Stress susceptibility index (SSI) (Fischer & Maurer 1978)

$$SSI = \frac{1 - \left(Y_s / Y_p\right)}{SI}$$

Where SI is stress intensity and calculated as:

$$SI = 1 - \left(\frac{\overline{Y_s}}{\overline{Y_p}}\right)$$

(3.) Tolerance (TOL) (Clarke et al. 1992)

$$TOL = Y_p - Y_s$$

(4.) Mean productivity (MP) (Hossain 1990)

$$MP = \frac{Y_p + Y_s}{2}$$

(5.) Geometric Mean Productivity (GMP) (Fernandez 1992)

$$GMP = \sqrt{Y_s \cdot Y_p}$$

(6.) Harmonic Mean (HAM) (Fernandez 1992)

$$HAM = \frac{2(Y_p \times Y_s)}{Y_p + Y_s}$$

(7.) Yield Index (YI) (Gavuzzi et al. 1997)

$$YI = \frac{Y_s}{\overline{Y_s}}$$

The data were statistically analyzed for each season and then combined for both years by SAS and MSTATC softwares. Mean comparison was conducted using the Duncan's Multiple Range Test (DMRT). Additional statistical analysis such as regression, correlation, path and cluster analysis were done by SPSS (ver. 16).

Results

In order to study on effects of genotype and drought stress on rapeseed traits, analysis of variance in stress and normal conditions was done as simple and combined forms. Analysis of variance in normal conditions showed that there were significant differences among the genotypes for seed yield, plant height, stem diameter, branches number per plant, biological yield, duration of flowering, pods number per plant, pod length, seeds number per pod and harvest index (data not shown).

Analysis of variance in drought stress conditions showed that there were significant differences among the genotypes for plant height, branches number per plant, duration of flowering, seeds number per pod, harvest index and oil content (data not shown).

Mean comparison using the Duncan's Multiple Range Test showed that Hyola420 indicated the highest seed yield in normal conditions (4505.30 kg/ha). Seed yield reduced from 3955.1 to 2800.96 kg/ha (29.18%)

Results of Table 1 shows that the average height of oilseed rape genotypes under stress conditions has been decreased compared to normal conditions (3.70%).

Mean comparison confirmed that Hyola308 genotype had the highest plant height in normal (180.00 cm) and water deficit (173.66 cm) conditions.

Mean comparison showed that Hyola420 had the highest stem diameter in normal (14.33 mm) and drought (10.26 cm) conditions. The results showed that in all varieties of stem diameter was reduced under stress conditions than under normal irrigation.

Results of Table 1 showed that the average stem diameter of rapeseed rape genotypes under stress conditions has been decreased compared to normal conditions (28.35%).

Mean comparison showed that Option500 had the highest number of branches per plant in normal (10.50 seeds) and drought (7.83 seeds) conditions. The results showed that in all varieties, stem diameter was reduced under stress conditions than under normal irrigation. Results of Table 1 showed that the average number of branches per plant of rapeseed rape genotypes under stress conditions has been decreased compared to normal conditions (24.68%).

Mean comparison showed that Sarigol and Amica genotypes had the highest biological yield in normal (16435 kg/ha) and drought (13994 kg/ha) conditions respectively. The results showed that in all varieties, the biological yield was reduced under stress conditions than under normal irrigation. Results of Table 1 showed that the average biological yield of rapeseed rape genotypes under stress conditions has been decreased compared to normal conditions (7.67%).

Analysis of variance showed that there was a significant variation among the genotypes for days to flowering trait. Mean comparison in non- stress conditions showed that RGS00 and Hyola401 genotypes with 209.66 days after emergence and genotype Amica with 203.33 days after emergence have known as late and early- ripe genotypes respectively. Also mean comparison in drought stress conditions showed that RGS00 and Hyola401 genotypes with 202.66 days after emergence and genotype Amica with 195.66 days after emergence have known as late and early-ripe genotypes respectively.

Table 1. Average of studied traits in normal and drought stress condition and the loss percent of traits in rapeseed (*B. napus*).

Days to flowering	Biological yield kg/ha)	Number of branches	Stem diameter (mm)	Plant height (cm)	
206.00	14287.91	9,52	13.05	168.80	Average (Normal site)
199.26	1319.74	7.17	9.35	158.70	Average (Stress site)
7.47	1096.17	2.35	3.70	6.10	The loss
-3.27	-7.67	-24.68	-28.35	-3.70	The loss percent

Results of Table 1 showed that the average days to flowering of rapeseed rape genotypes under stress conditions has been decreased compared to normal conditions (3.27%).

Analysis of variance showed that there was a significant variation among the genotypes for days to end of flowering trait. Mean comparison in non- stress conditions showed that Hyola401 genotype with 237.66 days after emergence and genotype Amica with 233.00 days after emergence have known as late and early- ripe genotypes respectively. Also mean comparison in drought stress conditions showed that Hyola308 genotype with 234.00 days after emergence and genotype Amica with 229.33 days after emergence have known as late and early- ripe genotypes respectively.

Results of Table 1 showed that the average days to end of flowering of rapeseed rape genotypes under stress conditions has been decreased compared to normal conditions (1.71%).

Analysis of variance showed that there was a significant variation among the genotypes for duration of flowering trait. Mean comparison in normal conditions showed that Hyola442 genotype with 32.66 days and genotype RGS00 with 27 days have the highest and lowest flowering duration respectively. Also mean comparison in drought stress conditions showed that Hyola42, Hyola308, Hyola420 and Amica genotypes with 33.66 days and genotype Hyola401 with 30.00 days have known showed the highest and lowest flowering duration respectively.

Results of Table 1 showed that the average flowering duration of rapeseed genotypes under stress conditions has been increased compared to normal conditions (9.14%).

Analysis of variance showed that there was a significant variation among the genotypes for days to days to seed maturity. Mean comparison in non- stress conditions showed that Kimberly genotype with 271.33 days after emergence and genotype Option 500 with 266.00 days after emergence have known as late and early- ripe genotypes respectively. Also mean comparison in drought stress conditions showed that Hyola42 and RGS00 genotypes with 267.00 days after emergence and Amica and Option500 genotypes with 264.33 days after emergence have known as late and early- ripe genotypes respectively.

Results of Table 1 showed that the average days to seed maturity of rapeseed genotypes under stress conditions has been decreased compared to normal conditions (1.29%).

Duncan's mean comparison showed that Hyola420 and Hyola308 genotypes indicated the highest pods per plant in normal and stress conditions (200.33 and 114.33 pods) respectively.

Results of Table 1 shows that the average pods per plant of oilseed rape genotypes under stress conditions has been decreased compared to normal conditions (32.54%).

Mean comparison showed that Kimberly had the highest pod length (8.30 cm) in normal and drought (7.03 cm) conditions. The results showed that in all varieties, pod length was reduced under stress conditions than under normal irrigation. Results of Table 1 showed that the average pod length of rapeseed rape genotypes under stress conditions has been decreased compared to normal conditions (14.69%).

Mean comparison showed that Hyola308 cultivar had the highest seeds per pod (29.66 cm) in normal and drought (27.26) conditions. The results showed that in all varieties, seeds per pod were reduced under stress conditions than under normal irrigation. Results of Table 1 showed that the average seeds per pod of rapeseed rape genotypes under stress conditions have been decreased compared to normal conditions (7.75%).

Mean comparison showed that RGS00 cultivar had the highest 1000 seed weight (4 g) in normal and drought (3.80 g) conditions. The results showed that in all varieties, 1000 seed weight were reduced under stress conditions than under normal irrigation. Results of Table 1 showed that the average 1000 seed weight of rapeseed rape genotypes under stress conditions have been decreased compared to normal conditions (6.06%).

Mean comparison showed that Kimberly cultivar had the highest harvest index (47.16%) in normal conditions. The Hyola420 cultivar had the highest harvest index (48.20%) in drought conditions

The results showed that in all varieties, harvest index were reduced under stress conditions than under normal irrigation. Results of Table 1 showed that the average harvest index of rapeseed rape genotypes under stress conditions have been increased compared to normal conditions (2.42%).

Mean comparison showed that Hyola420 cultivar had the highest oil content (30.06) in normal (24.87) conditions. Results of Table 1 showed that the average oil content of rapeseed rape genotypes under stress conditions have been decreased compared to normal conditions (22.03%).

Combined analysis of variance showed that drought stress effects on seed yield.Line × conditions interaction effect were not significant for any traits. This analysis showed that environment conditions had significant effects on plant height, stem diameter, lateral shoot number, biological yield, flowering duration, days to maturity, pod per plant, seed per pod, 1000 seed weight, seed yield and harvest index. The cultivar × conditions interaction effect was not significant for any traits.

Correlation analysis (Table 2) showed that there is a significant relationship between seed yield and pods per plant (0.698) and pod length (0.553).

Regression analysis using backward method showed that stem diameter, biological yield, days to flowering end and oil percent entered to seed yield model and explained

Table 2. Correlation coefficient between studied traits in rapeseed (*B. napus*).

Traits	Seed yield	Days to flowering	Days to end of flowering	Late flowering	Flowering duration	Days to maturity	Plant height	Pods per plant	Seeds per pod	Pod length	1000 seed weight
Seed yield	1.00										
Days to flowering	0.083	1.00									
Days to end of flowering	0.041	0.951**	1.00								
Late flowering	0.320	0.793**	0.830**	1.00							
Flowering duration	0.279	0.761**	- 0.640**	-0.295	1.00						
Days to maturity	0.123	0.648**	0.732**	0.643**	-0.328	1.00					
Plant height	0,324	0.559*	0.520*	0.474*	-0.386	0.706**	1.00				
Pods per plant	0.698**	-0.129	-0.209	-0.065	0.031	-0.100	0.349	1.00			
Seeds per pod	0.270	0.155	0.257	0.264	0.052	0.227	-0.098	-0.661**	1.00		
Pod length	0.553**	0.163	0.291	0.255	0.068	0.245	-0.069	-0.686**	0.977**	1.00	
1000 seed weight	0.030	-0.257	-0.263	-0.328	0.080	-0.187	-0.232	0.456	-0.533*	- 0.567*	1.00

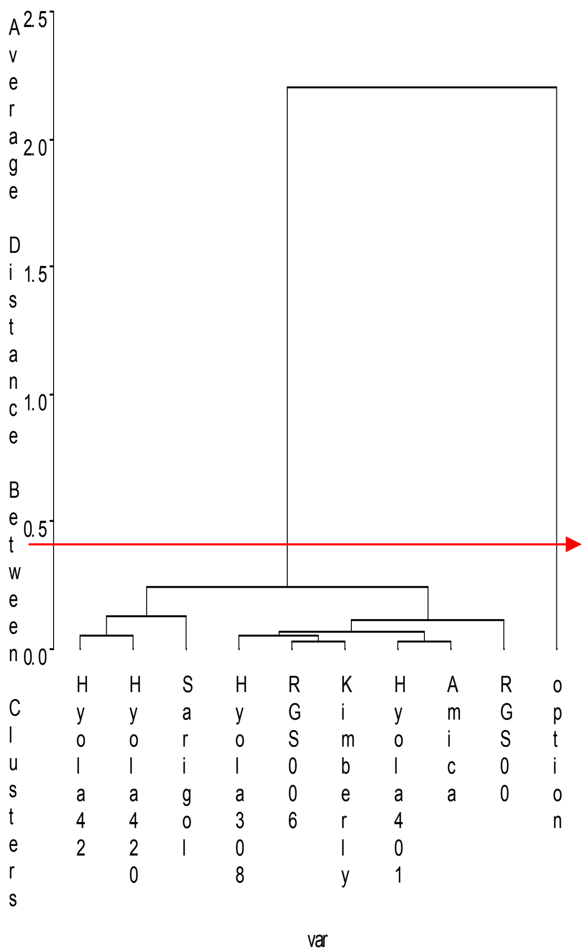

Figure 1. Cluster analysis for rapeseed cultivars in irrigated conditions.

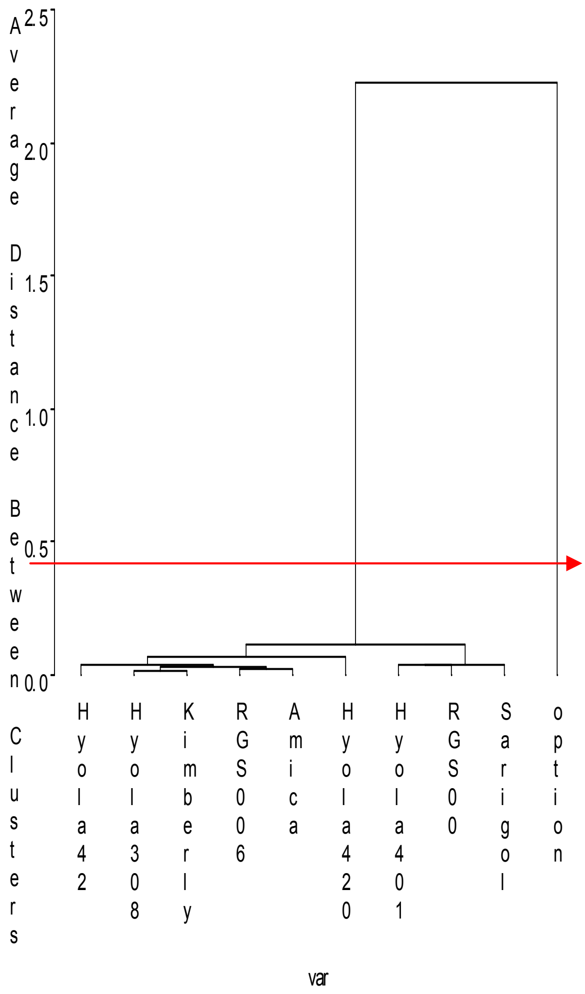

Figure 2. Cluster analysis for rapeseed cultivars in drought conditions.

57% of data.

Path analysis based on regression analysis results showed that plant height, pod per plant, seed per pod and 1000 seed weight had the highest direct effect on seed yield. Cluster analysis results showed that oilseed rape lines were divided to 3 groups under both conditions (Figs 1, 2). Analysis of variance for indices showed significant differences between cultivars for MP, STI and GMP.

Discussion

Rapeseed is an important oilseed crop in the agricultural systems of numerous arid and semiarid areas where its yield is often restricted by water deficit and high temperatures during the reproductive growth. Seed yield can be primarily limited even by the relatively short period of soil moisture shortage during the reproductive development (Chaghakaboodi et al. 2012a).

Water stress is the most limiting factor for canola production in semi-arid regions of the world (Nasri et al. 2008).The effect of water stress on plant is a function of genotype, duration and intensity of stress, weather conditions and developmental stages of rapeseed (Robertson & Holland 2004). The occurrence time is more important than the water stress intensity (Korte et al. 1983).

Physiological processes such as photosynthesis, cell turgidity and cells growth are highly affected by water stress (Muhammad Tahir et al. 2007).

Gunasekara et al. (2006) reported the grain yield reduction of *Brassica napus*, and *Brassica 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.

Our study revealed that there were significant differences among the genotypes for many traits in normal conditions. Since diversity is the basis for selection of superior and desirable varieties, population diversity can be considered for selection to provide superior genotypes. Comparison of the analysis of variance in normal and stress conditions showed that genotype variation is more in normal condition. Then genotype differences are shown in normal condition well. In other word, the drought stress had a significant effect on plant phenotype and performance.

The mean of pods per plant under stress conditions has been reduced compared to normal conditions. Mouhouche et al (1998) 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.

Wrigth et al. (1995) 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.

Water stress affected significantly the pod numbers per plant and the number of seeds per pod. Usually, when water deficit stress is applied after the flowering stage, it causes the number of pod per plant to reduce by shortening the flowering period, the reproductive growth duration, and finally the infertility of some flowers and their abscission (Nasri et al. 2008).

Mouhouche et al. (1998) 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 (Sionit & Kramer 1997). Wrigth et al. (1995) 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.

Jones et al. (1985) showed a water deficit during flowering stage influenced significantly the number of seeds whereas deficit of water after pollinating decreased the seed size. These findings are supported by those of Rathore & Patel (1990) who reported higher number of pods and number of seeds per pod at higher irrigation frequencies. It is clear 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 reason of seeds numbers reduction per pod during deficit water stress are reducing number of flowers and lowering number flowers which converted to seed. On the one hand, transmitting materials from phloem depend on both photosynthesis which provide 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 reduce the phloem photosynthesis materials and finally assimilation amount which lead to increasing vulnerability of seed formatting under deficit water conditions.

As average height of canola genotypes under stress conditions decrease compared to normal conditions, it seems the fact that as canola plant is an indeterminate crop, the occurrence of drought during flowering stage, stop the vegetative growth and accelerate reproductive growth. On the other hand, early reproductive growth and reduction in vegetative growth period in stress conditions leads to competition between vegetative and reproductive organs. Reduction of leaf area leads to decreasing in the photosynthetic materials. This situation leads to more competition and reduced plant height.

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.

Reduction in drought stress leads to increasing in attracts elements and then more photosynthesis. Thus assimilates will be produced properly and allocated to the vegetative growth and then plant height is increased; because stress reduces photosynthesis through stomatal closure and other properties and consequently reduces growth (Chaghakaboodi et al. 2012a).

In this study, it seems that water deficit has been severe enough to cause a significant decrease in the stem diameter. On the other hand, early reproductive growth and reduction of vegetative growth under stress conditions and competition between vegetative and reproductive organs was a decrease in stem diameter.

In all varieties number of branches per plant was reduced under stress conditions. These results indicate that water stress at flowering stage acts negatively and mainly on number of branches per plant. This is due to a decrease in plant height at flowering stage. Since the canola is indeterminate plant, vegetative growth will continue after reproductive growth initiation. Moisture stress at flowering stage leads to stop in vegetative growth and assimilation (Muhammad Tahir et al. 2007).

Due to reduced branch number followed by stress, causing reduced production and stimulating branch primordia and reducing in transport of assimilates (Kahrizi & Allahvarand 2012).

Darjani et al. (2013) demonstrated that the interaction of cultivar × irrigation regime on the number of branches per plant is effective. Water deficiency and drought conditions significantly reduce the number of branches per plant.

The results showed that in all varieties biological yield was reduced under stress conditions. The results indicate that drought stress limit the plant vegetative and reproductive growth. Khalili et al. (2012) also reported that biological yield of canola cultivars has been decreased under drought stress.

Decreasing of average days to flowering under stress conditions indicate the effects of environmental changes on beginning of flowering trait. Then flowering initiation date could be changed by environmental changes. Early flowering as a desirable trait for canola cultivars can protect the plant against warm weather. Then pod and seed filling was occurred before the beginning of critical stresses. It also the early flowering prevents flowering period and seed filling synchrony with aphid activity (Chaghakaboodi et al. 2012b).

Average days to end of flowering under stress conditions have been decreased. Early flowering in rapeseed is a mechanism of escape from drought stress. Water stress during the final stages of reproductive accelerates the senescence in the plant, since it is associated with a decrease in grain filling period. One of the plants strategies for dealing with drought is capacity for vegetative and extending of flowering period (Chaghakaboodi et al 2012b).

In drought stress conditions the most seeds are immature and then lead to seed or pod shattering. Thereby during the flowering period indirectly affect the yield and yield components. The flowering period can be prolonged aphid activity period on a canola field increases. Also prolonged flowering period can be increased the aphid activity period on a canola field. Then flower formation is prevented and phyllody disease may be developed (Kahrizi & Allahvarand 2012).

Under stress conditions, average days to seed maturity have been decreased; that indicate the effects of environmental changes on days to seed maturity trait. The results indicate that stress limits the plant vegetative and reproductive growth. On the other hand, earlier reproductive growth and reduction of vegetative growth period in stress conditions leads to competition between the vegetative and reproductive organs and the seed yield is reduced (Kahrizi & Allahvarand 2012).

Guttieri et al. (2001) reported that drought stress reduced grain yield caused by low kernel growth rate, whereas Altenbach et al. (2003) found that grain filling shortening caused kernel size and yield reductions.

Number of pods per plant is sum of pods in main branch and branches. A rapeseed plant produced around 4000 flower buds in perfect condition and the low density of flower buds. Of these, according to genotype, environment and density 5 to 20 percent of them may be produce flower. Others will be abscised. In finally, 5 to 20 percent of flowers will be remained and 50 percent of them may be produce seed.

In canola, number of pods per plant is an important index for seed yield. It seems that main part of the yield loss in drought stress is due to reduction of pods per plant and number of seeds per pod. The number of pods per plants is sensitive to drought stress. Darjany et al. (2013) demonstrated that the interaction of cultivar × irrigation regime is effective on the number of pods per plant. Khalili et al (2012) reported that drought stress reduced the number of pods per plant in rapeseed cultivars.

Kimberly cultivar had the highest pod length in normal and drought conditions. The results showed that in all varieties, pod length was reduced under stress conditions. Khalili et al. (2012) reported that canola cultivars pod length decreased under drought stress.

Seeds per pod in all varieties were reduced under stress conditions. Average seeds per pod of rapeseed rape genotypes under stress conditions have been decreased. Kimber et al. (1995) reported initial water stress during pod growth, affected the number of those. According to Gregorie (2007) abiotic stress by restricting the supply of assimilates for grain filling influence number of seeds per pod. Din et al. (2011) reported that the number of seeds per pod cultivars significantly affected by stress during early stages of flower and pod filling. Darjany et al. (2013) demonstrated that the interaction of cultivar × irrigation regime is effective on the number of seeds per pod.

The results showed that in all varieties, 1000 seed weight were reduced under stress conditions. Results showed that part of the yield loss in stress conditions is related to the reduction of seeds weight.

It must be defined that at seed forming stage and at the end of growing period, all different parts of plant acted as sink and assimilate all their stored photosynthesis matters to seed. So any drought stress at this stage caused to fading, becoming small and thinning of the seeds. It also suggested that drought stress at seed forming stage influenced mainly 1000-seed weight and resulted in decreasing of it (Nesmith & Ritchi 1992).

The 1000-seed weight is influenced by their filling speed and duration. Abiotic stresses such as drought especially at seed forming and filling decrease the seed filling speed and duration and finally its weight due to photosynthesis reduction. Pandy et al. (2001) showed that during water deficit stress at flowering stage, the seed yield decreases due to reducing seeds weights. Deloche (1980) showed that drought stress at seed filling stage caused to producing faded seeds. Keati & Cooper (1998) proposed that decreasing seed weight under water deficit stress resulted from harmful effect of drought on producing biomass and drought stress caused to reducing seed weight. They also indicated in their study on effect of irrigation treatments on canola yield that all seed yield components decreased seed yield under drought condition.

The average harvest index of rapeseed rape genotypes under stress conditions has been decreased. Khalili et al. (2012) reported that drought reduced harvest index in rapeseed cultivars.

Results showed that the average oil content of rapeseed rape genotypes under stress conditions have been decreased compared to normal conditions.

Triboi-Blondel & Renard (1999) showed that oil content was decreased during deficit water stress in order to physiological care. 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 the other hand, the plant growth duration was decreased under drought stress conditions, enough time isn't available to crude protein, carbohydrates and therefore oil content of seed was decreased under these conditions.

As there is significant relationship between seed yield and pods per plant and pod length, then for plant breeding and selection, it is possible that pods per plant and pod length be selected. Grain yield is a complex trait and is greatly influenced by various environmental conditions. Breeding programs depend on the knowledge of key traits, genetic systems controlling their inheritance, and genetic and environmental factors that influence their expression (Kahrizi et al. 2010). Pod numbers per plant, seed and oil yield of canola is decreased by water stress (Rahnema et al. 2006).

Seed yield potential of rapeseed crops depends on the events occurring prior to and during the flowering stage, while the reproductive period is most susceptible to stress (Mendham & Salisbury, 1995). Severe stress decreases the duration of reproductive growth and stress during flowering or ripening stages results in large yield losses (Hall 1992).

Analysis of variance for drought indices demonstrated significant differences among cultivars for MP, STI and GMP. With consideration of correlation between indices and yield under stress and non-stress, these indices were identified as the best indices for isolation and selection of tolerant cultivars.

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