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An assessment of the response of 20 canola (*Brassica napus* L.) genotypes to drought stress during flowering

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ABSTRACT

The present study was conducted to evaluate the canola (Brassica napus L.) Genotypes responses to drought stress and different growing conditions. According to this, 20 genotypes of canola were cultivated at two different regions and irrigated normally until flowering stage. The canola irrigation was cut at the flowering stage and canola genotypes sense drought stress from flowering stage until harvesting stage. In this experiment, the yield and yield components were recorded for all genotypes. Results showed that canola genotypes had a different response to drought stress. Moreover, it was observed that canola yield and also its yield components formation were significantly affected by interaction of genotype and growing conditions. The canola seed yield, number of silique per plant, seed number in silique, 1000-seed weight, seed oil content and oil yield was significantly reduced due to drought stress. It was found that 1000-seed weight had the highest effect on the canola seed yield formation, in comparison with other yield components. According to our results, it can be concluded that the canola response to drought stress was genotype-dependent. It was also concluded that 1000-seed weight could be a suitable trait for selection of the canola genotypes.

Key-words: Oil content, Canola yield, Oil content, Path analysis.

INTRODUCTION

Drought is one of the main environmental constraints to agricultural productivity worldwide. Regarding to plants growing in a defined growth season, water availability in the soil is one of the most important factors affecting the plant growth and development.The water deficit in the soil has an evident effect on plant growth that depends on both severity and duration of the stress [5-8-9].Moreover, the time of the drought stress occurrence also can be important. It has been noted that drought stress during the cropping season can directly affects grain yield, particularly at the reproductive stage. There are many findings that confirmed the yield loss by drought stress occurred in the reproductive stages [19-28-38-50]. However, the response of the plant to drought stress occurring at the reproductive stages could be depend on the genotype, growing conditions, plant shape, plant development type, etc. The genus Brassica is one of 51 genera in the tribe Brassiceae belongs to the crucifer family, and is the economically most important genus within this tribe, containing 37 different species [14].Canola (*Brassica napus* L.) is an amphidiploid species derived from interspecificcrossesbetweenB.Oleracea and B.Rapa [32].Canola is grown as oilseeds in manycountries of the world, and it is the most productive Brassica oilseed speciesunder cultivation. Canola oil is currently the lowest saturated fat vegetable oil and is a main source for human oil consumption in the world. So, its breeding and also response to abiotic stress are interested for researchers. The researchers are trying to find a canola variety which has a stable yield under unstable condition.

One of the abiotic factors affecting canola growth and yield is the soil water availability, special during different growth stages. Although the canola yield has been frequently evaluated under drought stress [3-12-13-29-36-51]. There is a possibility to find a genotype, which gives better function than previous genotypes, especially under drought stress. So, study the canola genotypes and also use the selection method could be a suitable strategy in the canola improvement. The main differences between canola genotype responses to drought stress may be related to the component yield variation under drought stress. Regarding to this study the canola yield components could be open a new procedure for finding a suitable cultivar of canola.The present research was conducted to study the canola genotype responses to drought stress occurring at flowering stage and then select the best genotype for use in the dried regions and also for application in the breeding programs. Moreover, the yield components variation of canola was also assessed in the mentioned situation.

MATERIALS AND METHODS

The research was conducted intwo regions of Iran, in 2015-2016. One of the fields was located at BashtCounty, in Kohgiluyeh and Boyer-Ahmad province.The on other field was located at RostamCounty, in in Fars province. Both of the experimentswere conducted as factorial experiment, including genotype and irrigation regimes factors with 3 replications. In each experiment, 20 canola (*Brassica napus L.*) genotypes were cultivated. The genotypes name is presented in the Table 1.After canola cultivation, the irrigation regime was applied as two types. In the first treatment, irrigation regime was applied in a relevant application (based on 80 mm evaporation from pan class A), as control treatment. The second irrigation regime was applied as drought stress at flowering stage of canola which irrigation was stopped at this stage and continued until the end of the growing period. Each experiment plot was 6 m^2. The fertilizers (N, P, and K) were added to the field based on the soil requirement. After treatments applied, the plants were harvested and the yield and yield components were recorded. The yield components were included: silique number per plant, seed number per silique and 1000-seed weight.

Table 1.Canola genotype used in this experiment.

KS21	AS17	KS18	KRS 19	KRS 33	KRS 17	SS 48	SS 29	KRS28	KRS64	Name
10	9	8	7	6	5	4	3	2	1	Code
AS29	KS66	AS25	SS32	KS41	AS22	KS14	AS12	AS18	KS16	Name
20	19	18	17	16	15	14	13	12	11	Code

The seed oil content and finally oil yieldwere calculated for canola genotypes. The seed yield content was calculated by NAR systems and it was present in the weight percentage. Thereafter, the seed oil percentage was multiplied to seed yield in order to find the oil yield [41]. In order to find the yield components portion in the final seed yield formation of canola, a path analysis was conducted. According to this, the direct and indirect effect of yield components was assessed. In order to analysis the experimental data, both of the field experiment were arranged in a combined analysis design involving two factorial experiments. The data were analyzed by analysis of variance in the format of the general linear model (GLM) using SAS software.Thereafter, the least significant difference (LSD) method was used in or to comparison of the treatment means. The path analysis was done by SPSS package software. The histograms were provided by Excel.

RESULTS AND DISCUSSION

Results showed that genotypes yield was significantly affected by environmental condition and also affected by the interaction of genotype and drought stress (Table 2).

Table 2. Analysis of Variance for yield and yield components of Canola (*Brassica napus*L.) genotypes treated by drought stress and different growing locations

(S. O. V)	df	Mean of Squares (MS)					
		Seed yield	Silique in plant	Seed in silique	1000 seed weight	Oil content	Oil yield
Place	1	26^{**}	1279	349^{**}	0.76*	0.08	4.1^{**}
Rep (Place)	4	0.58^{**}	538	11.9^{*}	0.08	2.5	0.1^{**}
Drought stress	1	228^{*}	141705^{*}	5201	35^{*}	577	47^{*}
Place×Drought stress	1	0.14	0.95	811	0.04	8.3^{**}	0.1^{*}
Genotype	19	1.6^{**}	873^{*}	15.9^{**}	1^{**}	4.6	0.3^{**}
Genotype×Place	19	0.18	359	3.9	0.23^{**}	46.5^{**}	0.05^{**}
Genotype×drought stress	19	0.63^{**}	559	5.3	0.2	2.5^{*}	0.11^{**}
Place×Genotype×drought stress	19	0.14	262	7.2	0.1	1	0.02
Error	156	0.15	252	4.6	0.12	1.2	0.028
Coefficient of Variation (%)	-	13.7	17.2	9.1	12.9	2.7	14.1
Coefficient of Determination (R^2)	-	0.92	0.82	0.90	0.77	0.93	0.93

*** and *, significant at 0.01 and 0.05, respectively.*

It was observed that the yield of Canola was decreased (21%, in comparison with field 1) in the field 2 (figure1). The interaction between Canola genotypes and drought stress showed that Canola genotypes didn'thave thesame responses to drought stress (Figure 1). In the normal condition, the highest (4.5 t/ha) and lowest (3.11 t/ha) yield were observed in the genotype 4 and 15, respectively. In the drought stress condition, genotypes 1 and 18 showed the highest (2.8 t/ha) and lowest (1.07 t/ha) yield, respectively. The highest yield loss was occurred in the genotypes 8 and 9 and minimum yield loss was observed in the genotype 14.

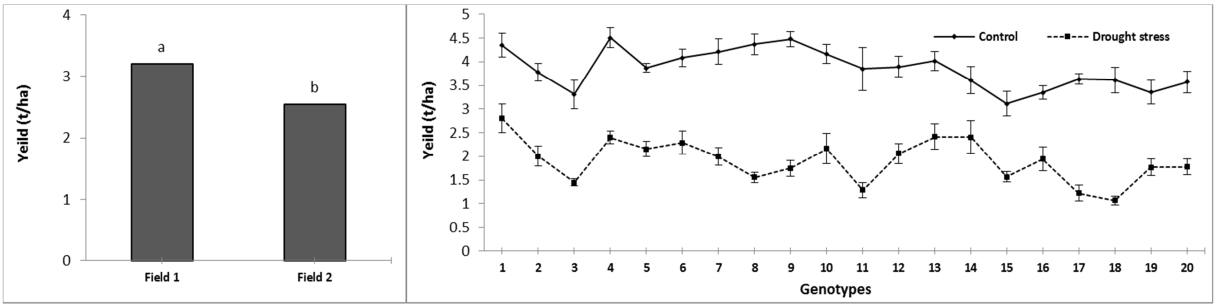

Figure 1. Seed yield of Canola (*Brassica napus* L.) genotypes in two locations and different conditions of soil water content.

It was observed that the number of silique per canola was significantly affected by genotype and drought stress (Table 2). A significant loss (41%, in comparison with control) in the silique number was observed due to drought stress (Figure 2). Results showed that canola genotypes were variant in the silique number production, as the highest (109 siliques) silique number was observed in the genotype 4 which was not significantly different with genotypes 1, 2, 5, 6, 7, 8, 10, 12 and 13 (Figure 2). The minimum silique number (78 siliques) was observed in the genotype 19 which didn't show a significant difference with genotypes 20, 18, 17, 16, 15, 9, 10, 11 and 3 (Figure 2).

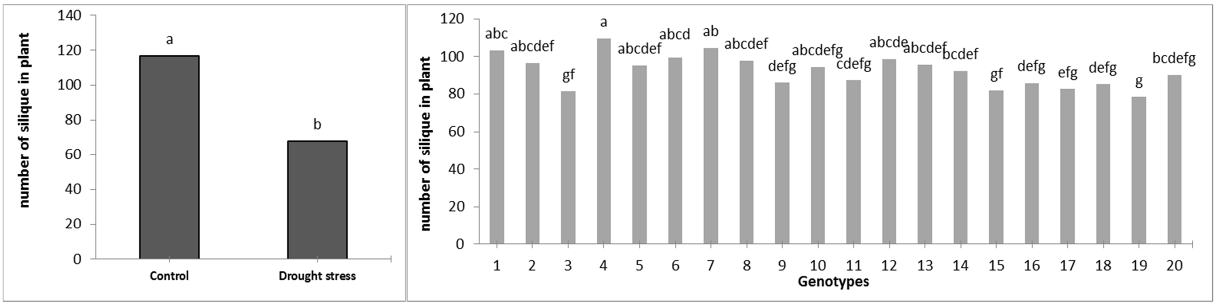

Figure 2. The number of silique among Canola (*Brassica napus* L) genotypes in two condition of soil water content

Results of analysis of variance showed that the seed number per silique was significantly affected by genotypes and also interaction of growing conditions and drought stress (Table 2). The seed number per silique of canola was significantly decreased by drought stress at the two fields, but the decreasing severity was not same in the both of the fields (Figure 3). The highest seed number per silique (31.2 seeds) was created under normal condition and in the field 1 (Figure 3). The lowest seed number per silique was observed under drought stress condition and in the field 1 (Figure 3). The loss of the seed number per silique in the field 1 and 2 were 41 and 22%, respectively. The seed number per silique was varied among the canola genotypes. The highest seed number per silique (25.81 seeds) was observed in the genotype 6 which didn't have significant differences with genotypes 1, 4, 7 and 14 (Figure 3).

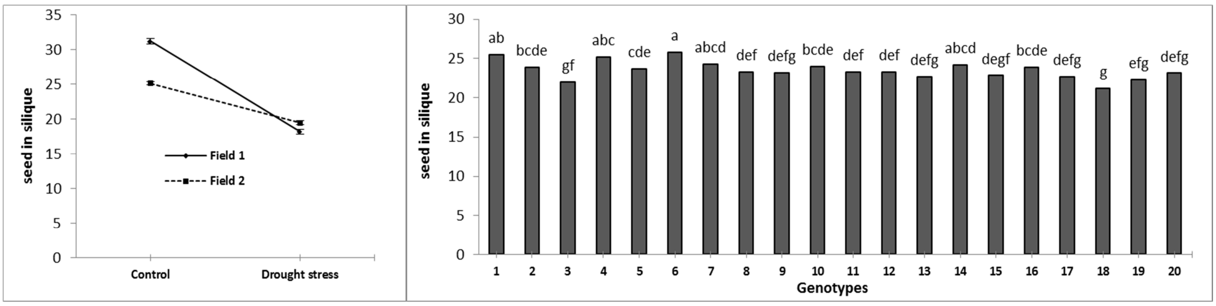

Figure 3. The seed number in silique of Canola (*Brassica napus* L.) genotypes in the two places and different condition of soil water content

The lowest seed number per silique (21.6 seeds) was observed in the genotype 18 which was statistically same with genotypes 20, 19, 17, 15, 13, 9 and 3.It was seen that 1000-seed weight of canola genotypes was significantly affected by drought stress and interaction between genotype and growing conditions (Table 2). The results clearly showed that 1000-seed weight of canola was significantly decreased (24%, in comparison with control) by drought stress (Figure 4). The results showed that 1000-seed weight of canola was dependent on the growing conditions and genotype, as the highest 1000-seed weight (3.6 g) was observed in the genotype 5 under field 1 and the lowest (2.17 g) was observed in the genotype 17 under field 1 condition (Figure 4).

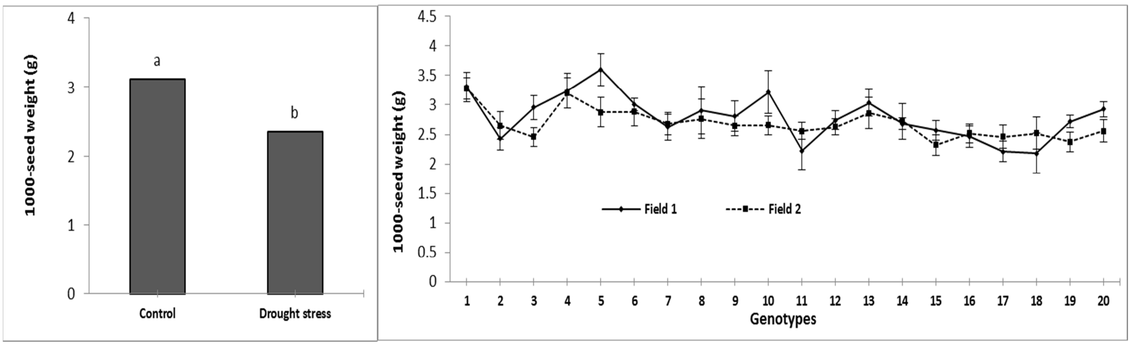

Figure 4. The 1000-seed weight of Canola (*Brassica napus* L.) genotypes in the two places and different condition of soil water content

It was observed that seed oil content of canola was significantly affected by double interactions of growing conditions and drought stress condition, genotype and growing condition, genotype and drought stress (Table 2). Although drought stress decreased the seed oil content, the decreasing severity was dependent on growing conditions. The maximum and minimum of canola seed oil content (43.1% and 38.9%, respectively) were observed in the in the field 2 and in the normal and drought stress conditions, respectively (Figure 5). The seed oil losses in the field 1 and 2 were 4.5% and 9%, respectively (Figure 5). Regarding to seed oil content variations, the canola genotypes showed different responses under different growing conditions. The highest (42.9%) and lowest (40.5%) seed oil content of canola was observed under field 1 and in the genotypes 10 and 18, respectively (Figure 5). The results clearly showed that drought stress significantly decreased the seed oil content in all genotypes (Figure 5). In this object, the highest of seed oil content of canola (44.5%) was observed in the genotype 4 growing in normal condition and the lowest seed oil content (38%) was seen in the genotype 17 growing in the drought stress condition. The maximum (12%) and minimum (4) seed oil content losses causing by drought stress were observed in the genotype 1 and 10, respectively.

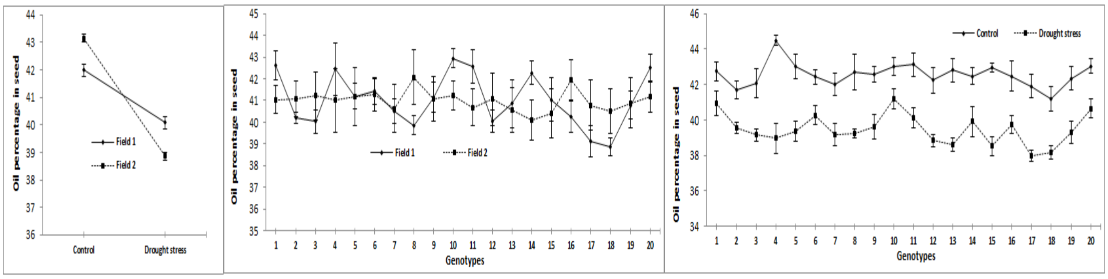

Figure 5. Oil percentage in the seed of Canola (*Brassica napus* L) genotypes in two places and different condition of soil water content

Results showed that double interactions of growing conditions and drought stress condition, genotype and growing conditions, genotype and drought stress significantly determined the final oil yield of canola (Table 2). The oil yield of canola was significantly decreased by drought stress under both of the fields (Figure 6). The oil yield loss caused by drought stress in the field 1 and 2 were 48% and 60%, respectively. Regarding to this, the maximum oil yield (1.8 t/ha) was observed in the normal condition and in the field 1 (Figure 6). The minimum oil yield (0.6 t/ha) was observed under drought stress and in the field 2. By looking at the interaction effect of genotype and growing conditions, it was seen that the highest oil yield (1.7 t/ha) was created in the genotype 1 and in the field 1, while the lowest oil yield was observed in the genotypes 3, 11 and 15 (0.9, 0.9 and 0.8 t/ha, respectively) and in the field 2 (Figure 6). Totally, it can be said that a high oil yield of canola was produced in the field 1. The results clearly revealed that the oil yield of canola was significantly decreased by drought stress, but with different ranges among canola genotypes (Figure 6). Regarding to the interaction effect of drought stress and genotype, the highest oil yield (2 t/ha) was observed in the genotype 4 growing under normal condition (statistically same with genotypes 1, 8 and 9) while the lowest oil yield (0.4 t/ha) was observed in the genotype 18 growing in the drought stress condition (statistically same with genotypes 17 and 11). The maximum (72%) and minimum (36% and 37%) oil yield losses caused by drought stress were occurred in the genotype 18, 14 and 1, respectively.

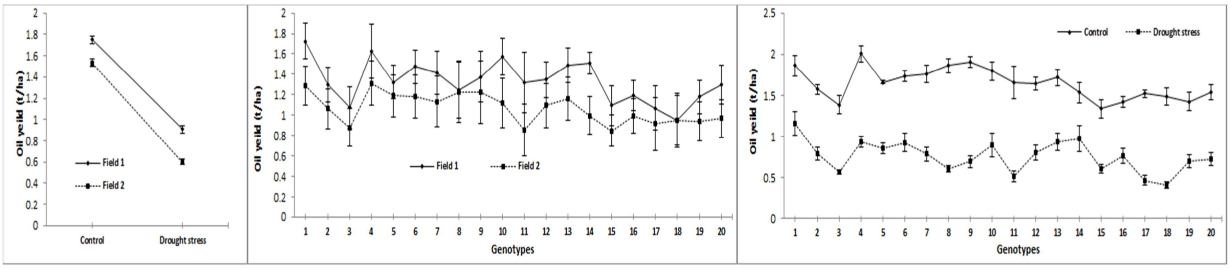

Figure 6. Oil yield of Canola (*Brassica napus* L.) genotypes in two places and different condition of soil water content

Path analysis ofcanola yield components showed that 1000-seed weight had the highest direct effect on the canola yield under both of normal and drought stress conditions (Figure 7). It was also observed that the direct effect of 1000-seed weight was more under drought stress condition. In other words, the role of 1000-seed weight in the canola yield was more determinant under drought stress. Followed by 1000-seed weight, the silique number per plant was the important part of the canola yield and the seed number in silique was the last component. Similarto 1000-seed weight, it was observed that the direct effect of silique number was more important under drought stress condition.

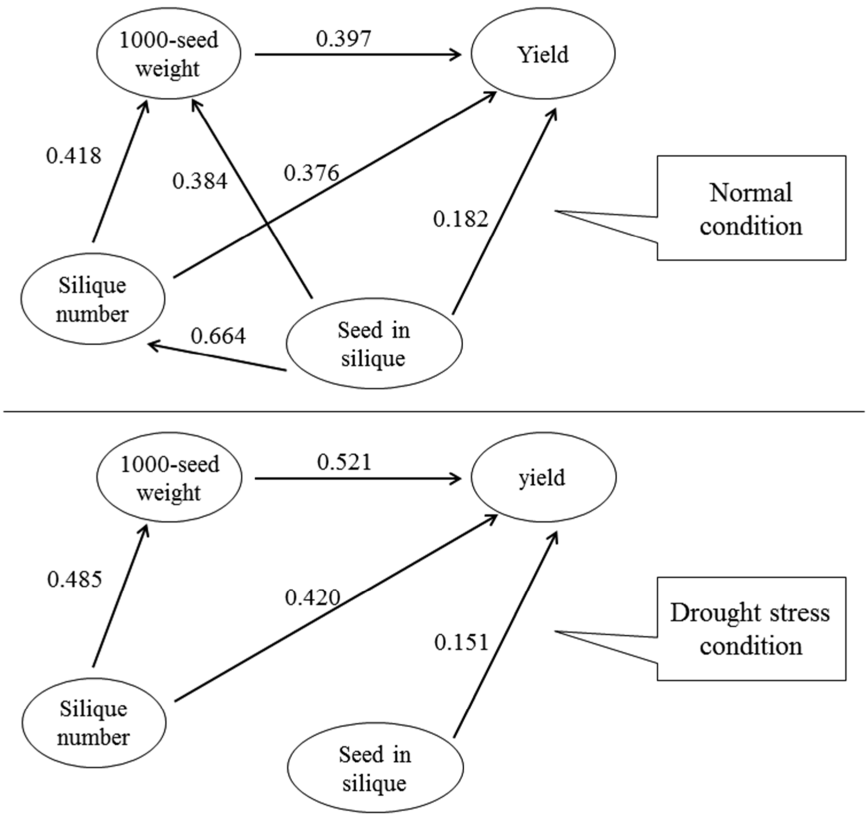

Figure 7. Path analysis for yield components of Canola (*Brassica napus* L.) under normal and drought stress conditions

The yield loss of canola in the second field could be due to the variation in the growth condition and means that the yield of canola is environment dependent. Moreover, it was found that the canola genotypes response to the drought stress was different. This result can help researcher to select the canola variety according to the minimum variation in its economic yield. Drought stress occurring during flowering stage can reduce the canola yield, as observed in the present research. Similarly, it has been reported that a drought stress during flowering stages reduced the canola yield in 30% [13]. It is believed that flowering stage is the more sensitive stage related to drought stress and the response of canola to drought stress in this stage could be dependent on genotype, as observed in our experiment [6-34-35]. Water limitation causes a reduction in assimilatescompounds and then can reduce the yield. Our results are compatible with some previous results[15-16-24-27-51] and can be used as breeding tools for section the tolerant cultivars for drought regions. Accordingly, some genotypes such as 1, 4 and 14 could be cultivated in the arid regions, due to the high yield and also high stability in their yield under drought stress.

The silique number per plant is a main part of the canola yield components and it has been reported that silique number could be reduced by 21% when drought stress occurred at the flowering stage [11-13]. It seems that reproduction of canola was so sensitive to water shortage because the silique number was significantly reduced by drought stress. This result can be an acceptable reason for canola yield loss in the present study. The limitation in the translocation of photosynthetic products to inflorescence and sink strength reduction by hormonal have reported as the main reasons for silique number reduction under drought stress[44].The silique number reduction by drought stress have been reported by researchers and our result are compatible with previous results [23-43].Although the low heritability of silique number has been reported [49], our results showed that canola genotypes had different potential in the silique production. These results mean that the silique production in the canola could be a gene dependent trait and could be used as a selection tool for canola breeders. Our results suggest that genotype 4 could be a cultivar with high potential in the silique production.

The present study showed that the seed number in the silique was dependent on growing conditions. As occurred in the present research, it has been reported that lack of the photosynthesis product and environmental factors could limit the seed production in the silique of canola [25]. Many researchers believed that the seed number in the silique is the most sensitive yield components of canola in response to drought stress [10-22-35]. It has been also reported that stress can reduce the pollen number and viability and decrease pollen germination on pistil and then reduce the yield[26-34]. The genotype dependence of seed number in silique has been previously reported [1]. According to our results, an extensive genetic diversity among canola genotype could be considered and this result can help canola breeders to find a high potential cultivar.For example, genotype 6 in this research could be suggested as suitable cultivar having a high seed number in silique. Regarding to this object, it has been suggested that selection the cultivars with high seed numbers in silique and with high 1000-seed weight are useful to find the cultivars with high yield [47], because the seed number in silique is one of the main factors affecting the sink size.In other word, the more seed number in silique gives the more sink strength.

The 1000-seed weight is depend on assimilates flow from the leaves and photosynthetic tissues. Accordingly, every interference in this flow can affect the 1000-seed weight. It seems that the photosynthetic potential decreased by drought stress, because the 1000-seed weight was decreased under drought stress condition.The assimilates translocation needed hydrostatic pressure originating water in the fluem and it seems that the water limitation affects the assimilates translocation in the canola tissues. The 1000-seed weight is mainly determined at the green filling stage and is a function of grain filling rate and duration [34].Genetic and environmental factorscould affect the 1000-seed weight [21-27].It has been noted that drought stress on the end of the reproductive stage could create a source limitation due to loss of the leaves [2]. Our results are in agreement with previous findings [18-37-51]. The effectiveness of growing condition on the 1000-seed weight is demonstrating that this trait is less geneticdependent, in comparison with the seed number trait. According to this, is not appropriate for genotype selection.

The seed oil content is usually 40%, but it can be varied by environmental condition [20]. The oil biosynthesis is dependent on photosynthetic products. In general, drought stress decreases the seed oil content in canola and this process was observed in this study [17-43-45]. According to our results, it can suggest that genotype 4 was most sensitive and genotype 1 and 10 were more stable in oil content production. These results states that genotypes such as genotypes 1 and 10 can be used in the arid regions due to low oil content losses. Similarly, it has been reported that drought stress reduced the canola seed oil content [7]. The same resultshave been reported by researchers [23-46-51].

The oil yield loss was occurred in two parts: first, in the seed yield and yield components an second, in the seed oil content. However, it can be said that genotype 1 had a better function, in comparison with other genotypes, because had a high seed yield and also had a low oil yield loss. It has been reported that the seed oil content of canola was decreased by drought stress, which resulted in the oil yield loss [13-49]. Drought stress at the flowering stage mainly caused a yield loss through decrease in silique number in canola, consequently decrease the seed and oil yield [42]. Our results are in agreement with Shabani, et al. (2013) who observed a significant decrease in the oil yield of canola under drought stress condition [40].

The canola yield components could be affected by environmental factors which change their portion relating to final seed yield. Totally, water stress reduces the yield components values in canola [31].The path analysis demonstrated that mechanisms involving in the grain filling (such as remobilization) are so important for drought stressed plants. In other word, cultivars capabiling in the more grain filling are suitable for drought stress condition. Same to our results, Özer et al., (1999) showed that 1000-seed weight had the highest portion in the yield formation of canola, in comparison with other yield components [30]. A same result has been also reported by Clarke and Simpson (1978) [10]. In an experiment, the canola genotypes yield has been studied and it has been reported that 1000-seed weight had the most direct effect on canola yield [36]. The same results have been also reported [4-39-48]. According to our results, it can be said that the role of the 1000-seed weight and silique number for final yield formation is more important under drought stress. It means that silique production and preservation under drought stress is a useful trait and could be used as a selection standard for canola. Same to this result, showed that silique number was sensitive to drought stress [13]. So, a genotype with high silique could be used for drought condition. It was also found that seed number per silique had low direct role in yield formation of canola0.

CONCLUSION

According to our results, it can be concluded that canola genotype had different responses to drought stress and growing conditions and the genotype functionwas usually complicated by environmental factors. It was also found that canola yield and canola seed oil content were decreased by drought stress. Among the canola genotypes, genotypes 1, 4 and 14 were found better than others, in response to drought stress. By path analysis, it was revealed that 1000-seed weight had the highest direct effect on the yield formation in the canola while the seed number per silique showed the lowest direct effect.

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