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THE STUDY OF THE DROUGHT TOLERANCE OF CANOLA (*Brassica napus* L.) CULTIVARS BY USING STRESS TOLERANCE INDICES

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Abstract

To study the drought tolerance of the different canola cultivars by the evaluation of drought tolerance indices, fourteen canola cultivars were planted and studied in the research farm of Karaj area under both normal and stress conditions. For this purpose, the randomized complete block design (RCBD) with three replications was employed. The results indicate that SML046 and Sarigol cultivars have the mean seed yield respectively. The results of the combined analysis of variance showed that seed yield had had significant difference. The analysis of correlation between drought tolerance indices showed that there is a positive significant correlation between most indices. In addition, the analysis of the components shows that the first two factors explain approximately 99.93% of the variance. The cultivars were studied by the analysis of the data using drought tolerance indices. According to the indices TOL and SSI, the cultivars Talaye 13 and Hyola401 were the most tolerant cultivars to drought stress. According to the indices GMP and MP, the cultivars Licord and SLM046 were the most tolerant ones. Based on Harm index, the genotypes Sarigol and SLM046 were the most tolerant ones and finally, according to the STI index, the cultivar Sarigol had the highest tolerance for drought stress. The results of the study of correlation between the indices of drought stress tolerance indicate that there is a positive significant correlation between most indices. According to the results obtained from the bi-plot depicted from the two main components, the indices MP, GMP, and TOL are the best indices.

Key words: *canola, drought stress, combined analysis, factor analysis, tolerance indice.*

INTRODUCTION

At least one third of the entire world is classified as arid and semi-arid regions. Drought is the most common environmental stress that restricts almost 25 percent of the productions of the lands of the world (Bates et al., 1973). 40 % of the canola (*Brassica napus* L.) is seed oil and protein in meal and therefore, it is considered as one of the main seed oils of the world during the recent decades (Raymer, 2002). In addition, this plant is economically the fifth top plant after rice, wheat, barley, and cotton (Cardoza & Stewart, 2003). Fischer and Maurer (1978), Rosille and Hambilin (1981), Fernandez (1992), and Kristin et al. (1997) have introduced respectively stress sensitivity index (SSI), tolerance index mean productivity index (Mp), and geometric mean productivity (GMP). The cultivars, which have identical or are to some extent different in yield under stress or stress-free conditions, have relative tolerance for drought. One of the important factors used for the evaluation of the drought tolerance of cultivars is the quantitative measurement of drought tolerance criteria (Clark et al., 1992). By the study of the genotype yield in the normal condition and stress condition, Fernandez classified into four groups in terms of their reactions to these two conditions: Group A: Genotypes with high yield in both normal and stress environment; Group B: Genotypes with high yield only in normal condition; Group C: Genotypes with high yield only in stress condition; Group D: Genotypes with low yield both in normal and stress conditions.

The genotypes with high yield in both conditions are appropriate for improvement purposes (Fernandez, 1992). The results of the studies conducted by Qifuma et al. (2006) on canola showed that water scarcity stress has a negative impact on seed yield in flowering and seed filling. The purpose of this study is to study and identify the genotypes that are tolerated for drought in canola cultivars, and study the reaction of the cultivars to drought stress.

Some researchers suggest selecting the cultivars with high yield in ideal conditions (Bertan et al., 2003) and some others recommend selecting those that produce high yields under stress conditions (Ceccareli & Grando, 1991). However, there are reports indicating that the selection of the cultivars with high seed yield under both stress and stress-free is more effective in the identification of resistant cultivars (Clark et al., 1992; Fischer & Maurer, 1978;Rajaram and Ginkle, 2001; Fernandez, 1992)

To study the drought tolerance of the cultivars, the following indices have been employed:

Stress Susceptibility Index: this index (SSI) was suggested by Fischer and Maurer. The low value of SSI is the indication of minor changes in genotype yield in both stress and stress-free conditions.

$$SSI = \frac{1-(Y_S/Y_P)}{SI}$$

Tolerance Index: TOL was introduced by Rosille and Hambilin (Rosille & Hambilin, 1981). The high value of TOL is an indication of genotype sensitivity to stress.

$$TOL = Y_P - Y_S$$

Arithmetic mean:

$$MP = \frac{Y_P + Y_S}{2}$$

Stress Tolerance Index: STI was introduced by Fernandez (Fernandez, 1992). The genotypes with high STI based on this index are more stable.

$$STI = \frac{(Y_P)(Y_S)}{(Y_P)^2}$$

Geometric Mean: another index, which was introduced by Fernandez, is the Geometric Mean Productivity. In comparison to MP, this index is more effective in terms of the separation of genotypes.

$$GMP = \sqrt{Y_s \times Y_P}$$

Harmonic Mean:

$$Harm = \frac{2Y_pY_s}{Y_P+Y_S}$$

MATERIALS AND METHODS

To study the drought tolerance in canola cultivars by evaluating tolerance indices, fourteen canola cultivars (Table 1) were farmed and evaluated in the research farmland of Karaj branch of the Islamic Azad University in 2010-2011 under both normal and stress drought conditions. The test was conducted in form of a randomized complete block design with three replications. The tested cultivars included Modena ‹Okapi ‹Hyola401 ‹Licord ‹Opera ‹ Zarfam ‹RGS003 ‹SLM046 ‹Sarigol ‹ Hyola308‹Hyola330 ‹Talaye 13 ‹Hyola6, and Option 500.

All tillage land leveling and grading were done completely. Each experimental plot was divided into four rows 50 centimeters distant from each other and in a length of 2 meters. The phases of stress were gone through after flowering stage. To eliminate marginal effects and reduce errors, sampling was conducted only from the middle rows of each plot. The analysis of variance (ANOVA) was conducted on the quantitative value of indices in form of randomized complete block design (RCBD). Moreover, the correlation between tolerance indices and seed yield was calculated in both stress and stress-free conditions. SAS and Minitab software programs were used to analyze the obtained data.

RESULTS AND DISCUSSIONS

The results of combined ANOVA obtained in both normal and stress conditions at the probability levels of 0.01 and 0.05 indicate a significant difference in the trait seed yield. The lack of significant difference in replication effects indicates the uniformity of test conditions. In addition, no significant difference was observed in genotype effect, genotype, and environment. The significance of genotype effect and genotype by environment interaction indicates the adaptability of the different genotypes with the different regions. The results of this analysis have been presented in the Table 2.

The data were analyzed based on the drought tolerance indices including TOL, MP, Harm, GMP, STI, and SSI. According to TOL index, the cultivar Talaye 13 (1.92) and Hyola 401 (1.97) are the most tolerant cultivars and SLM 046 (6.4) and Hyola 60 (5.8) have the least drought tolerance.

Contrary to TOL index, lower value of MP index indicates the higher sensitivity of genotypes to stress conditions. In this regard, the cultivars Licord (3.23) and SLMO46 (3.2) are the most tolerant genotypes than others. By contrast, the cultivars Talaye (0.96) and Hyola 401 (0.98) are more sensitive to drought in comparison to other genotypes.

In addition, the higher Harm, GMP, and STI indices are, the more tolerate the genotypes are for stress conditions. According to Harm index, the genotypes Sarigol (4.86) and SLM046 (4.03) have the highest resistance to stress conditions. According to this index, the most sensitive cultivars include Okapi (1.59) and Hyola 330 (1.77). Based on GMP index, the cultivars Licord (2.54) and SLM 046 (2.52) have the most tolerance for stress conditions, and the cultivars Hyola 401 (1.4) and Talaye 13 (1.38) have the least tolerance towards stress conditions. According to STI index, the cultivar Sarigol (9.85) is the most resistant cultivar to stress conditions and the cultivars Hyola 330 (2.27) and Okapi (2.13) are the least tolerant cultivars to stress conditions. Just like the TOL index, the high SSI index indicates the sensitivity of genotypes to stress. Therefore, any selection based on this index leads to the selection of genotypes with low yield under ideal conditions and by contrast, high yield under stress conditions. The cultivars Okapi (1.17) and Hyola 60 (1.18) are the most sensitive genotypes and the cultivars Talaye 13 (0.61) and Hyola 401 (0.74) are the most resistant to stress conditions. The results of this analysis have been have been provided in the Table 3.

The results of the correlation between the indices of drought tolerance indicate that seed yield in normal condition (Y_p) is in positive significant relation with all indices excluding SSI index. In addition, the trait seed yield in stress conditions (Y_s) is in positive significant correlation with the indices Harm and STI and in a negative significant correlation with the index SSI. TOL and MP indices are in positive and significant correlation with GMP and SSI. It is understood that any index with a high and identical correlation with the seed yield in both stress and stress-free condition is considered as the best index (Rosille & Hambilin, 1981). The correlation coefficients of the different indices with the yields in both stress and normal conditions show that Harm and STI indices that are in high correlation with the seed yield in stress and normal conditions can be used to identify fertile cultivars in both environmental conditions. In 1992, Fernandez concluded based on the results of the correlations of TOL, MP, and SSI with Y_s and Y_p that STI is the potential yield index and stress tolerance and it can separate the genotypes of the group A from those of other groups (Fernandez, 1992). In addition, the indices Harm is in positive significant correlation with STI and the index MP in the same correlation with SSI index. The results of this study have been provided in the Table 4.

Factor analysis has been employed to explain the correlation between many variables in the framework of low number of independent factors (Mohammadi & Rasanna, 2003). In addition, this statistical method is one of the oldest multivariate methods used to reduce data volume. Such reduction is carried out for describing multivariate data. This method is improved ideally when there is a significant linear correlation between the main variables (Johnson & Wichern, 1988). According to the factor-analysis conducted on 14 genotypes based on 6 indexes and two stress and non-stress conditions and presented in the table 5, the two first components (totally equal to 99.93%) explained the total changes in the data. In this test, the first component called stress tolerance index explains 63.68 % of the total changes in the data, and it had a high positive correlation with Y_p (0.44), as well as the indices TOL (0.41), MP (0.41), and GMP (0.40). The second component explains 37.25 % of the total changes in the data, and is in high positive correlation with the yield in stress condition (0.49) and negative correlation with the yield under non-stress condition (-0.008). In addition, the second component had a negative correlation with the indices TOL (-0.22), MP (-0.22), GMP (-0.23), and SSI (-0.52), and positive correlation with the indices Harm (0.41) and STI (0.38). This second one is called harmonic component.

In Figure 1, the results of the factor analysis, the genotypes G1, G8, G4, G6, and G7 have been put in the potential, yield stability, and drought tolerance area. In addition, the genotypes G14, G5, G11, and G13 have been put in the lower part and close to the sensitivity indices. This indicates the genetic diversity of genotypes in responding to drought conditions. According to the results shown in the Table 5, five genotypes G1, G8, G4, G6, and G7 located in the potential, yield stability, and drought tolerance, and having high MP, GMP, and TOL values are the most tolerance cultivars, and the genotypes G14 and G5 located on the border of two high and low potential, yield stability, and drought stress were identified as the semi-tolerant cultivars.

According to the results, the indices MP, GMP, and TOL acted identically in terms of the separation of the cultivars that are tolerant for drought, and identical genotypes were identified. Therefore, they are called the most appropriate indices for the identification of cultivars.

Table 1. The name and the origin of Canola genotypes evaluation in the experiment

Row	Genotypes	Origin	Row	Genotype	Origin	Row	Genotype	Origin
1	Modena	Russia	6	Zarfam	Iran	11	Talaye 13	Germany
2	Okapi	France	7	RGS003	Germany	12	Hyola 60	Canada
3	Hyola401	Canada	8	SLM046	Germany	13	Option 500	Germany
4	Licord	Germany	9	Sarigol	Germany	14	Hyola 330	Canada
5	Opera	Sweden	10	Hyola308	Canada			

Table 2. Combined analysis of variance of seed yield under normal and stress conditions

S.O.V	Df	SS	MS
Env	1	384.34	384.34^{**}
Block(env)	4	1.51	0.37^{ns}
Genotype	13	98.2	7.55^{**}
G×E	13	48.95	3.76^{**}
Error	52	53.52	1.02
CV			25.04

Table 3. the mean drought tolerance indices in both normal and stress conditions in Canola Cultivars

Cultivars	Yp	Ys	STI	SSI	GMP	Harm	Mp	TOL
Modena	7.62	2.17	6	1.03	2.33	3.38	2.72	5.45
Okapi	5.03	0.95	2.13	1.17	2.03	1.59	2.04	4.08
Hyola 401	3.81	1.84	3.6	0.74	1.4	2.48	0.98	1.97
Licord	8.46	2	5.81	1.1	2.54	2.23	3.23	4.46
Opera	5.34	1.7	3.92	0.98	1.9	2.57	1.82	3.64
Zarfam	6.64	1.86	4.81	1.04	2.18	2.91	2.39	4.78
RGS003	7.79	2.04	5.71	1.06	2.39	3.24	2.87	5.74
SLM046	9	2.6	7.8	1.02	2.52	4.03	3.2	6.4
Sarigol	7.75	3.54	9.85	0.78	2.05	4.86	2.1	4.21
Hyola 308	3.71	1.35	2.6	0.92	1.53	1.97	1.18	2.36
Hyola 330	3.91	1.15	2.27	1.02	1.66	1.77	1.38	2.76
Talaye 13	4.51	2.58	5.48	0.61	1.38	3.28	0.96	1.92
Hyola 60	7.1	1.29	3.44	1.18	2.4	2.18	2.9	5.8
Option 500	5.94	1.64	4	1.04	2.07	2.57	2.15	4.3

Ys is the genotype yield in environmental stress conditions, Yp the genotype yield in ideal conditions, TOL, MP, Harm, GMP, SSI, and STI are tolerance index, mean productivity, harmonic mean, geometric mean productivity, stress susceptibility index, and stress tolerance index respectively.

Table 4. The correlation between drought tolerance indices in stress and non-stress conditions

	YP	YS	TOL	MP	HARM	GMP	SSI	STI
YP	1	0.51*	0.92**	0.92**	0.69**	0.92**	0.39ns	0.72**
YS		1	0.15ns	0.15ns	0.97**	0.14ns	-0.56*	0.95**
TOL			1	1**	0.37ns	0.99**	0.69**	0.42ns
MP				1	0.37ns	0.99**	0.69**	0.99**
HARM					1	0.36ns	-0.35ns	0.99**
GMP						1	0.71**	0.41ns
SSI							1	-0.29
STI								1

ns, * and ** mean non-significant, significant at 5% and 1% levels respectively.

Table5. Linear combination principal components of drought tolerance indices

Component	Eigen-value	Variance Cumulative (%)	YP	YS	TOL	MP	HARM	GMP	SSI	STI
1	5.01	62.68	0.44	0.23	0.41	0.41	0.33	0.40	0.17	0.33
2	2.93	99.93	-0.008	0.49	-0.22	-0.22	0.41	-0.23	-0.52	0.38

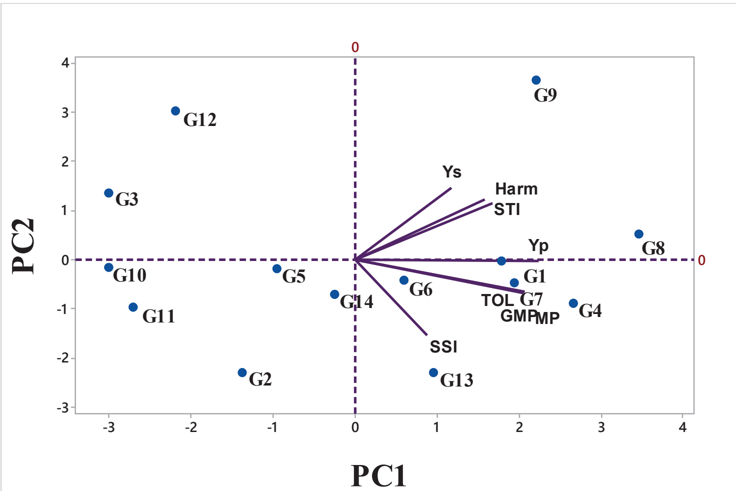

Figure 1. The bi-plot scheme of 14 canola cultivars based on the first and second main components (pc1 and pc2) obtained from 8 indices of drought tolerance and sensitivity

G1:Modena ‹G2:Okapi ‹G3:Hayola401 ‹G4:Licord ‹G5:Opera ‹G6:Zarfam ‹G7:RGS003 ‹G8:SLM046 ‹G9:Sarigol ‹ G10:Hyola308 ‹G11:Hyola330 ‹G12:Talaye13 ‹G13:Hyola60 ‹G14:Option500.

CONCLUSIONS

According to the indices TOL and SSI, the cultivars Talaye 13 and Hyola401 were the most tolerant cultivars to drought stress.

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REFERENCES

Bates L.S., Waldern R.P., Teave I.D., 1973. Rapid determination of free praline for water stress satndies. Plant and soil 39: 107-205.

Bertan F.J., Beak D., Banziger M., Edmeads G.O., 2003. Genetic analysis of inbred and hybrid grain yield under stress and nonstress environments in tropical maize.Crop Sci., 43:807-817.

Beweley J.D.J., Krochko E., 1982. Desiccation tolerance. Pp. 325-378. In O.L. Lange, P.S. Noble, C.B. Osmond, H. Zieyler (eds.). Physiological platecology. Vol. 2. Water relation and carbon assimilation. Springer. Varlay, New york.

Cardoza V., Stewart C.N., 2003. Increased Agrobacterium – mediated transformation and rooting efficiencies in canola (*Brassica napus* L.) from hypocotyls segment explant. Plant Cell Rep., 21: 599-604.

Ceccareli S., Grando S., 1991. Selection environment and environmental sensivity in barley. Euphytica, 57:157-167.

Clark J.M.,. Ronald M.D., Towenly-Smith T.F., 1992. Evaluation of method for quantification of drought tolerance in wheat. Crop Sci., 32:723-728.

Fernandez G.C., 1992. Effective selection criteria for assessing stress tolerance. Pp. 257- 270. In: Kuo C.G. (ed.). Proceedings of the International Symposium on Adaptation of Vegetables and food crops in Temperature and water stress. AVRDC Publications. Tainan, Taiwan.

Fischer R.A., Maurer R., 1978. Drought resistance in spring wheat cultivars. I. Grain yield response. Australian Journal of Agricultural Research, 29: 897-912.

Johnson R.A., Wichern D.W., 1988. Applied multivariate statistical analysis. Prentice Hall U.S.A., 33: 65-71.

Kristin A.S., Serna R.A., Perez F.I., Enriquez B.C., Gallegos J.A.A., Vallejo P.R., Wasiimi N., Kelley J.D. 1997. Improving Common bean performance under drought stress. Crop science, 27: 43-50.

Mohammadi S.A.P., Rasanna B.M., 2003. Analysis of genetic diversity in crop plants salient statistical tool and considerations. Crop Sci., 43: 1235-1248.

Qifuma Sh., Niknam R., Turner D.W., 2006. Resposes of osmatic adjustment and seed yield of *Brassica napus* and *B.kuncea* to soil water deficit at different growth stages. Aust. J. Agric. Res., 57:221-226.

Rajaram S., Van Ginkle M., 2001. Mexico, 50 years of international wheat breeding. In: Bonjean A.P., Angus W.J. (Eds.), The Wrold Wheat Book: A History of wheat Breeding. Lavoisiser Publishing, Paris, France, pp. 579-604.

Raymer P.L., 2002. Canola: an emerging oilseed crop. Pp. 122-126. In: Trends in new crops and new uses. Ganick, J. and whipkey, A.(eds.). ASHS press. Alexandia, VA.

Rosille A.A., Hambilin J., 1981. Theoretical aspects of selection for yield in stress and non-stress environments. Crop Sci., 21:43-46.