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Evaluating of Drought Stress Tolerance Based on Selection Indices in Spring Canola Cultivars (*Brassica napus* L.)

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Abstract

In order to study the response of nine cultivars spring canola (*Brassica napus* L.) to drought stress, an experiment was conducted in a factorial experimental on the basis of randomized complete block design with three replications under two irrigated conditions during 2009-2010 cropping season. Eleven drought tolerance indices including stress tolerance index (STI), stress susceptibility index (SSI), tolerance index (TOL), geometric mean production (GMP), mean production (MP), yield index (YI), yield stability index (YSI), drought resistance index (DI), modified stress tolerance (MSTI), relative drought index (RDI) and stress susceptibility percentage index (SSPI) were calculated based on grain yield under drought (Ys) and irrigated conditions (Yp).Yield in stress (Ys) and non-stress (Yp) conditions were significantly and positively correlated with STI, GMP, MP, YI, TOL, DI, RDI, YSI, SSPI, K_1STI and K_2STI and negatively correlated with SSI. Results of this study show thatthese indices of stress tolerance/resistance such as K_1STI, K_2STI, SSPI, RDI and DI can be used as the most suitable indicators for screening drought tolerant cultivars.Screening drought tolerantcultivars using ranking method discriminated cultivars Hyola 308, Heros and SW5001 as the most droughts tolerant. Cluster analysis classified the cultivars into three groups i.e., resistant, susceptible and tolerant to drought conditions. Therefore they are recommended to be used as parents for improvement of drought tolerance in other cultivars.

Keywords: Canola, drought stress tolerance indicators, ranking method

1. Introduction

Rapeseed (*Brassica napus* L.), from the *Brassicaceae* family, grows in about 42.2 million/ha in 53 countries all over the 6 continents, yielding an average of 1451 kg ha^{-1}. Although Asia alone itself owns 59.1% of the cultivated areas, it produces only 48.6% of the whole production. Canola (*Brassica napus* L.) has a high adaptability under the different environmental conditions especially under the drought, salinity and temperature stresses (Yadava & Singh, 2004).

All the alive and non-alive stresses are the most factors to reducing production nonetheless; drought stress is the most important factor limiting crops production in agricultural systems in arid and semi arid regions (Molasadeghi et al., 2011). Iran is located on the world's desert belt, and is considered as the arid and semiarid region. Average rainfall in the country is about 250 (mm) which this is one third of average rainfall in the world, while 1.2 percent of the world's land is allocated to Iran. On the other hand, of 18.5 million hectares of agricultural lands, 6.2 million hectares (33.5 %) is devoted to dry cultivation. A bout 1.2 million /ha of lands under dry cultivation, more than 400 (mm) rainfall will receive (Mohammadi et al., 2006). Loss of yield is the main concern of plant breeder sand hence emphasize on yield performance under stress conditions. Thus, drought indices which provide a measure of drought based on loss of yield under drought-conditions in comparison tonormal conditions have been used for screening drought-tolerant genotypes (Mitra, 2001). Various researchers have used different methods to evaluate genetic differences in drought tolerance. Drought resistance is defined by Hall (1993) as the relative yield of a genotype compared to other genotypes subjected to the same drought stress. Drought susceptibility of a genotype is often measured as a function of the reduction in yield under drought stress (Blaum, 1988) whilst the values are confounded with differential yield potential of genotypes (Ramirez & Kelly, 1998). Several selection criteria have been proposed to select genotypes based on their performance in stress and non–stress environments. Fischer et al. (1998) suggested that relative drought index (RDI) is positive indices for indicating stress tolerance. Lan (1988) defined new indices of drought resistance index (DI), which was commonly accepted to identify genotypes producing high yield under both stress and non stress conditions. Rosielle & Hamblin (1981) defined stress tolerance (TOL) as the differences in yield between stress and irrigated environments and mean productivity (MP) as the average yield of genotypes under stress and non-stress conditions. The geometric mean productivity (GMP) is often used by breeders interested in relative performance, since drought stress can vary in severity in field environments over years (Fernandez, 1992). Fischer and Maurer (1978) suggested the stress susceptibility index (SSI) for measurement of yield stability that apprehended the changes in both potential and actual yields in variable environments. Clarke et al. (1992) used SSI to evaluate drought tolerance in wheat genotypes and found year-to-year variation in SSI for genotypes and could rank their pattern. In spring wheat cultivars, Guttieri et al. (2001), using SSI, suggested that an SSI > 1 indicated above-average susceptibility to drought stress. The yield index (YI; suggested by Gavuzzi et al., 1997) and yield stability index (YSI) suggested by Bouslamaand Schapaugh (1984) in order to evaluation the stability of genotypes in the both stress and non-stress conditions. Stress Tolerance Index (STI) was defined as a useful tool for determining high yield and stress tolerance potential of genotypes (Fernandez, 1992). To improve the efficiency of STI a modified stress tolerance index (MSTI) was suggested by Farshadfar and Sutka (2002) which corrects the STI as a weight. Moosavi et al. (2008) introduced stress susceptibility percentage index (SSPI) for screening drought tolerant genotypes in stress and non-stress conditions.

The present study was undertaken to assess the selection criteria for identifying drought tolerance in spring canolacultivars, so that suitable cultivars can be recommended for cultivation in droughtprone areas of Iran.

2. Materials and Methods

2.1 Experimental Design and Plant Material

Nine cultivars of canola (*Brassica napus* L.) listed in Table 1were provided from Agricultural and Natural Resources Research Center of East Azerbaijan, Iran. They were assessed using a factorial experimental on the basis of randomized complete block design with three replications under two irrigated conditions during 2009-2010 growing season at the Research Farm of Payame Noor University of Mahabad Center, west Azerbaijan, Iran (latitude 36.46°N, longitude 45.43°E, Altitude 1385 m above sea level). The climate is characterized by mean annual precipitation of 330 mm, mean annual temperature of 12˚C. Sowing was done by hand in plots with four rows 1 m in length and 20 cm apart. All plots were irrigated after sowing and subsequent irrigations in beginning stem elongation were carried out after 75 and 125 mm evaporation from class A pan. At harvest time, yield potential (Yp) and stress yield (Ys) were measured from 4 rows 1 m in length.

Table 1. Cultivars of canola used for drought tolerance assessment

No	Cultivar	Growth type
1	Hyola308	spring
2	Comet	spring
3	Cracker	spring
4	Sarigol	spring
5	SW5001	spring
6	Amica	spring
7	Heros	spring
8	Olga	spring
9	Option500	spring

2.2 Calculate Indices

Eleven drought tolerance indices including Stress susceptibility index (SSI), Relative drought index (RDI), Stress tolerance index (STI), Geometric mean productivity (GMP), Tolerance (TOL), Mean production (MP), Yield index (YI), Drought resistance index (DI), Yield stability index (YSI), Stress susceptibility percentage (SSPI), Modified stress tolerance index (KiSTI), were calculated using the following relationships (Fischer &

Maurer, 1978; Fischer et al., 1998; Fernandez, 1992; Rosielle & Hamblin, 1981; Bouslama & Schapaugh, 1984; Lan, 1988; Moosavi et al., 2008; Farshadfar & Sutka, 2002):

$$SSI = (1-(Ys/Yp))/(1-(\bar{Y}s)/(\bar{Y}p)) \quad (1)$$

$$RDI = (Ys/Yp)/(\bar{Y}s\ /\ \bar{Y}p) \quad (2)$$

$$STI = (Ys\ \times Yp)/(\bar{Y}p^2) \quad (3)$$

$$GMP = \sqrt{Ys\ \times Yp} \quad (4)$$

$$TOL = Yp - Ys \quad (5)$$

$$MP = (Ys\ + Yp)/2 \quad (6)$$

$$YI = (Ys)/(\bar{Y}s) \quad (7)$$

$$DI = (Ys\ \times (Ys\ /\ Yp\ ))/\bar{Y}s \quad (8)$$

$$YSI = Y_S/Y_p \quad (9)$$

$$SSPI = ((Yp - Ys/2(\bar{Y}p\ )) \times 100 \quad (10)$$

$$ki\ STI,\ K_1 = {Y_p}^2/{\bar{Y}_p}^2 \ \ and\ K_2 = {Y_s}^2/{\bar{Y}_s}^2 \quad (11)$$

In the above formulas, Ys, Yp, $\bar{Y}s$ and $\bar{Y}p$ represent yield under stress, yield non-stress for each cultivar, yield mean in stress and non-stress conditions for all cultivars, respectively.

cultivars can be categorized into four groups based on their performance in stress and non-stress environments: cultivars express uniform superiority in both stress and non stress conditions (Group A), cultivars perform favorably only in non-stress conditions (Group B), cultivars gives relatively higher yield only in stress conditions (Group C), and cultivars perform poorly in both stress and non stress conditions (Group D). The optimal selection criterion should distinguish Group A from the other three groups. Three-dimensional plots among YS, Yp, and STI, showed the interrelationships among these three variables to separate cultivars of Group A from other groups (Fernandez, 1992).

2.3 Statistical Analysis

Correlation among indices and grain yield in two conditions and three-dimensional plots drawing were performed by SPSS ver. 16, Statistica ver.8 softwares, respectively.

3. Result and Discussion

3.1 Comparing Cultivars based on the Resistance/Tolerance Indices

To investigate suitable stress resistance indices for screening of cultivars under drought condition, grain yield of cultivars under both non-stress and stress conditions were measured for calculating different sensitivity and tolerance indices (Table 2). A suitable index must have a significant correlation with grain yield under both the conditions (Mitra, 2001). Based on the stress tolerance index (STI) and grain yield, Hyola308 and SW5001 were found drought tolerance with highest STI and grain yield under irrigation (non-stressed) condition, while Olga and Sarigol displayed the lowest amount of STI and grain yield under irrigation condition. Other cultivars were identified as semi-tolerance or semi-sensitive to drought stress (Table 2). Rosielle and Hamblin (1981) reported that stress tolerance index and mean productivity were defined as the difference in yield and the average yield between stress and non-stress conditions, respectively. Thus, the highest GMP and MP were related to the cultivars Hyola 308, SW5001 and Craker. According to tolerance index (TOL), Sarigol and Olga exhibited the most and SW5001 and Hyola308 the least relative tolerance, respectively. Mevlut and Sait (2011) indicated that the genotypes with high STI usually have high difference in yield in two different conditions. They reported in general, similar ranks for the genotypes were observed by GMP and MP parameters as well as STI, which suggests that these three parameters are equal for selecting genotypes.Also, according to DI and RDI indices selected the Hyola 308, SW5001 and Cracker as the most relatively tolerantcultivars while for SSPI the cultivars Sarigol, Olga and Comet were the most relative tolerant. According to K_1STI and K_2STI the cultivars Hyola 308, SW5001 and Cracker were the most relative tolerant. YI and YSI discriminated cultivars Hyola 308, SW5001 and Cracker were the most and Sarigol and Olga the least relative tolerant cultivars (Table 2). Ilker et al. (2011) concluded that MP, GMP and STI values are convenient parameters to select high yielding wheat genotypes in both stress and non-stress conditions whereas relative decrease in yield, TOL and SSI values are better indices to determine tolerance levels.

Table 2. Resistance/tolerance indices of canola cultivars under stress and non-stress condition

Cultivar	Yp (gm^{-2})	Ys (gm^{-2})	SSI	STI	GMP	MP	TOL	YI	YSI	DI	SSPI	RDI	K_1STI	K_2STI
Hyola308	1208.873	453.488	0.808	0.829	740.412	831.181	755.385	2.457	0.375	0.922	46.439	1.653	2.209	6.035
Comet	616.112	80.360	1.125	0.075	222.510	348.236	535.752	0.435	0.130	0.057	32.937	0.575	0.574	0.190
Cracker	969.829	237.035	0.977	0.348	479.461	603.432	732.795	1.284	0.244	0.314	45.050	1.077	1.422	1.649
Sarigol	468.789	37.448	1.190	0.027	132.496	253.119	431.341	0.203	0.080	0.016	26.518	0.352	0.332	0.041
SW5001	1181.399	368.307	0.890	0.658	659.634	774.853	813.092	1.995	0.312	0.622	49.987	1.374	2.110	3.981
Amica	698.931	108.363	1.093	0.114	275.205	403.647	590.568	0.587	0.155	0.091	36.307	0.683	0.739	0.345
Heros	864.037	181.949	1.021	0.238	396.498	522.993	682.088	0.986	0.211	0.208	41.933	0.928	1.129	0.971
Olga	534.160	56.921	1.156	0.046	174.371	295.541	477.239	0.308	0.107	0.033	29.339	0.469	0.431	0.095
Option500	777.640	137.532	1.065	0.162	327.033	457.586	640.108	0.745	0.177	0.132	39.352	0.779	0.914	0.555

3.2 Correlation Analysis

To determine the most desirable drought tolerant criteria, the correlation coefficients between Yp, Ys and other quantitative indices of drought tolerance were calculated (Table 4). In other words, correlation analysis between grain yield and drought tolerance indices can be a good criterion for screening the best cultivars and indices used. Yield in stress (Ys) condition was significantly and positively corrected with STI, GMP, MP, TOL, YI, YSI, SSPI, RDI and DI. Yield in non-stress (Yp) condition was significant and positively correlated with TOL, GMP, MP, STI, YI, YSI, SSPI, RDI and DI indicating that these criteria were more effective in identifying high yielding cultivars under different water conditions. Toorchi et al. (2012) showed that correlation between MP, GMP, Ys and Yp was positive. Dehghani et al. (2009) reported that GMP, MP and STI were significantly and positively correlated with stress yield.

Table 4. Correlation coefficient between Yp, Ys and resistance/tolerance indices

	Ys	Yp	SSI	STI	GMP	MP	TOL	YI	YSI	DI	SSPI	RDI	K1	K2
Ys	1													
Yp	0.97**	1												
SSI	-0.98**	-0.96**	1											
STI	0.99**	0.95**	-0.97**	1										
GMP	0.99**	0.99**	-0.99**	0.98**	1									
MP	0.98**	0.99**	-0.99**	0.97**	0.99**	1								
TOL	0.89**	0.97**	-0.92**	0.85**	0.93**	0.94**	1							
YI	1**	0.97**	-0.99**	0.99**	0.99**	0.98**	0.89**	1						
YSI	0.99**	0.98**	-1**	0.97**	0.99**	0.99**	0.92**	0.99**	1					
DI	0.98**	0.92**	-0.95**	0.99**	0.96**	0.95**	0.80**	0.98**	0.96**	1				
SSPI	0.89**	0.97**	-0.92**	0.85*	0.93**	0.94**	1**	0.89**	0.92**	0.8**	1			
RDI	0.97**	0.98**	-1**	0.97**	0.99**	0.99**	0.92**	0.99**	1**	0.96**	0.92**	1		
K1	0.96**	0.99**	-0.99**	0.98**	0.99**	0.99**	0.93**	0.99**	0.99**	0.95**	0.93**	0.99**	1	
K2	0.95**	0.9**	-0.94**	0.98**	0.94**	0.93**	0.76*	0.97**	0.94**	0.99**	0.76*	0.94**	0.94**	1

* and ** Significant at the 5% and 1% levels of probability, respectively

Farshadfar et al. (2001) believed that most appropriate index for selecting stresstolerant cultivars is an index which has partly high correlation with seed yield under stress and non-stress conditions. The observed relations were consistent with those reported by Toorchi et al. (2012) in canola and Golabadi et al. (2006) in durum wheat. Ehdaie and Shakiba (1996) in wheat found that there was no correlation between stress susceptibility and yield under optimum condition.

3.3 Three Dimensional Plots and Cluster Analysis

In order to identify drought tolerant cultivars, three dimensional plots were drawn (Figure 1). Three dimensional plots are presented to show the interrelationships among these three variables to separate the cultivars of group A (high yielding cultivars in both stress and non-stress conditions) from the other groups (B, C and D), and to illustrate the advantage of STI and GMP indices as selection criterion for identifying high-yielding and stress tolerant cultivars. In three dimensional plots, Hyola 308 and SW5001 were included in A group, this cultivars had stable grain yield in stress and non-stress conditions. The cultivars Heros and Craker were in B group and performed favorably only in non-stress condition. Sarigol, Amica, Olga, Comet and Option 500 were in D group that performed poorly in both conditions. Cluster analysis showed that the cultivars, based on indices tended to group into three groups with 7, 4 and 3 genotypes, respectively (Figure 2). In this analysis, the first group had the highest MP, GMP, YI, YSI, DI, RDI, K1, K2 and STI, and was thus considered to be the most desirable cluster for both growth conditions. The second group had mean indicators values. Therefore, the cultivars of this group were considered to be stable non-stress conditions. In the third group, all cultivars had high SSI, thus they were susceptible to drought and only suitable for irrigated conditions.

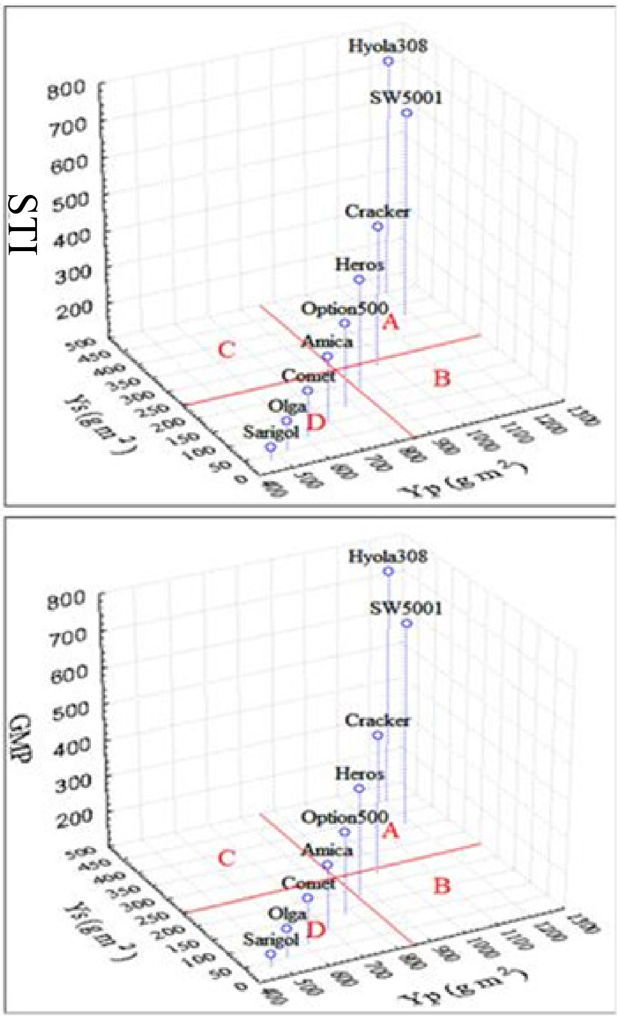

Figure 1. The three dimensional plots among STI, GMP, Yp and Ys

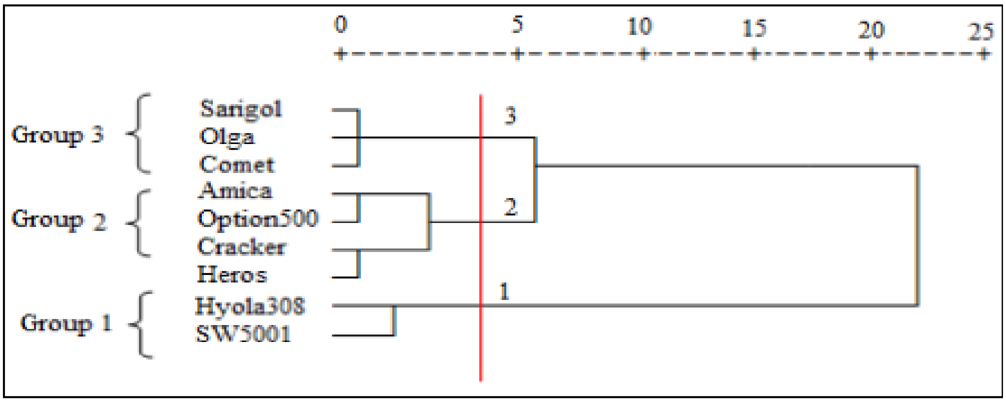

Figure 2. Dendrogram using Ward method between groups showing classification of cultivars based on resistance/tolerance

3.4 Ranking Method

The estimates indicators of drought tolerance (Table. 2) indicated that the identification of drought tolerant cultivars based on a single criterion was contradictory. Different indices introduced different cultivars as drought tolerant. To determine the most desirable drought tolerant cultivar according to the all indices, mean rank and standard deviation of ranks of all drought tolerance criteria were calculated and based on these two criteria the most desirable drought tolerant cultivars were identified. In consideration to all indices, cultivars Hyola308, SW5001 and Cracker exhibited the best mean rank and almost low standard deviation of rank, hence they were identified as the most drought tolerant cultivars, while cultivars Sarigol, Olga and Amica as the most sensitive (Table 3).

Table 3. Rank (R), rank mean ($\bar{R}$) and standard deviation of ranks (SDR) of drought resistance/tolerance indices

Cultivar	Yp (gm^{-2})	Ys (gm^{-2})	SSI	STI	GMP	MP	TOL	YI	YSI	DI	SSPI	RDI	K_1STI	K_2STI	$\bar{R}$	SDR
Hyola308	1	1	1	1	1	1	8	1	1	1	8	1	1	1	2.08	2.63
Comet	7	7	7	7	7	7	3	7	7	7	3	7	7	7	6.43	1.45
Cracker	3	3	3	3	3	3	7	3	3	3	7	3	3	3	3.57	1.45
Sarigol	9	9	9	9	9	9	1	9	9	9	1	9	9	9	7.86	2.91
SW5001	2	2	2	2	2	2	9	2	2	2	9	2	2	2	3	2.54
Amica	6	6	6	6	6	6	4	6	6	6	4	6	6	6	5.71	0.73
Heros	4	4	4	4	4	4	6	4	4	4	6	4	4	4	4.29	0.73
Olga	8	8	8	8	8	8	2	8	8	8	2	8	8	8	7.14	2.18
Option500	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0

4. Conclusion

Correlation between indices of stress tolerance and yield in both conditions, identify the most suitable indicators for screening drought tolerant cultivars. However, according to these results of correlation analysis other indices of stress tolerance/resistance such as K_1STI, K_2STI, SSPI, RDI and DI can be used as the most suitable indicators for screening drought tolerant cultivars.

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