Study the Drought Tolerance of Some of Oilseed Lines Using Different Stress Tolerance Indices

Shokoufeh Sharifi
MSc. Student of agronomy, Islamic Azad University, Kermanshah Branch
Email: sharifi0272@yahoo.com

Abbas Rezaei Nezhad
Scientific member of Kermanshah Research Organization

Lia Shoushtari Kermanshahi
Scientific member of Islamic Azad University, Kermanshah Branch

Abstract

Iran is located on the world’s desert belt, and is considered as the arid and semiarid region. Drought is one of the major abiotic factors of environmental stresses which limits growth and distribution of natural vegetation more than that of any other factors viz. extreme temperature, cold, heavy metals, drought and salinity. Drought stress determines the success or failure of plant establishment. The adverse effects of drought on growth and development of crop plants are of multifarious nature and could affect at all the growth stages of plant growth. In order to study of drought stress tolerance of different canola (*Brassica napus* L.) genotypes, a field experiment was conducted on the basis of randomized complete block design with three replications under two irrigated conditions from 2012-2014 years at the Agricultural Research Station of Islamabad Gharb, Kermanshah province, Iran. Seven drought tolerance indices including Stress susceptibility index (SSI), Stress tolerance index (STI), Geometric mean productivity (GMP), Tolerance (TOL), Mean production (MP) Yield index (YP) were calculated. According to results from drought stress resistance (SSI), drought stress tolerance (TOL) at flowering stage, KS12 and at pod forming stage Karaj3 genotype was determined as superior genotypes. And according to MP, GMP and STI indices, KS7 and KR4 at flowering stage and KR4 and KS7 at pod forming stage, placed in first and second ranks by a little difference which were similar with SSI and TOL indices.

Keywords: drought, stress, tolerance, canola, yield

Introduction

Crop responses to drought stresses involve processes modulated by water deficit at morphological, anatomical, cellular and molecular levels. The changes which occur in all plant organs in response to water stress decrease plant photosynthesis resulting in grain yield deduction. It would be very useful to develop effective strategies to reduce drought stress damage to crop plants. A strategy involves producing a high yielding genotype with traits leading toward drought tolerance (Safavi et al., 2015). Drought is one of the major physical factors of environmental stresses which limits growth and distribution of natural vegetation more than that of any other factors viz. extreme temperature, cold, heavy metals, drought and salinity (Safavi et al., 2015). Drought stress determines the success or failure of plant establishment. The adverse effects of drought on growth and development of crop plants are of multifarious nature and could affect at all the growth stages of plant growth. The susceptibility, severity and duration of plants exposition to drought stress varies in dependence of stress degree, different accompanying stress factors, plant species and their developmental stages but germination is regarded as most critical stage of plant life (Safavi et al., 2015).

Stress tolerance index (STI) was defined as a useful tool for determining high yield and stress tolerance potential of genotypes (Fernandez, 1992). Rosielle and 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 more than one indicated above-average susceptibility to drought stress. The yield index (YI) suggested by Gavuzzi et al. (1997), yield reduction ratio (YR) suggested by Golestani-Araghi and Assad (1998) in order to evaluation the stability of genotypes in the both stress and non-stress conditions. 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.

Many statistical procedures have been used by plant breeders to evaluate the effectiveness of several drought resistance indices for screening and identification of drought tolerant genotypes. For selection based on a combination of indices, some researchers (Golabadi et al., 2006, Majidi et al., 2011) have used principal component analysis (PCA). PCA is one of the most successful techniques for reducing the multiple dimensions of the observed variables to a smaller intrinsic dimensionality of independent variables (Johnson and Wichern, 2007). Ranking methods and biplot analysis have been used for screening drought tolerant cultivars (Khalili et al., 2012), Farshadfar and Elyasi (2012) in wheat and Farshadfar et al. (2012) in bread wheat. Keeping the importance of production of canola crop in view, the present study was aimed to evaluate the effectiveness of several drought resistance indices for screening and identification of drought tolerant wheat genotypes using different statistical procedures.

2. Material and Methods

2.1. Experimental Design and Plant Material

Nineteen cultivars of canola (Brassica napus L.) listed in Table 1 were provided from Agricultural and Natural Resources Research Center of Kermanshah, Iran. They were assessed using randomized complete block design with three replications under two irrigated conditions from 2012-2014 years at the Agricultural Research Station of Islamabad Gharb, Kermanshah province, Iran (between 34°8'E and 47°26'N, Altitude 1346m above sea level). The climate is characterized by mean annual precipitation of 422 mm, mean annual temperature of 13°C. Sowing was done by hand in plots with four rows 5 m in length and 20 cm apart.

2.2. Calculate Indices

Seven drought tolerance indices including Stress susceptibility index (SSI), Stress tolerance index (STI), Geometric mean productivity (GMP), Tolerance (TOL), Mean production (MP)

Yield index (YP) were calculated (Fischer et al., 1998; Fernandez, 1992; Rosielle & Hamblin, 1981; Farshadfar & Sutka, 2002):

[1] $SSI=((1-(Ys/Yp)))/((1-(Ys/Yp)))$
[2] $STI=((Ys/Yp))/((Ys/Yp))$
[3] $GMP=\sqrt{(Ys * Yp)}/$
[4] $TOL=Yp-Ys$
[5] $MP=(Ys+Yp)/2$

In the above formulas, Ys, Yp, 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 on 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. 20 software.

3. Results and Discussion

Using mean grain yield at studied environments, stress sensitivity index (SSI), drought tolerance (TOL), mean productivity (MP), stress tolerance index, geometric productivity mean (GPM) were calculated and presented in Tables 1 and 2.

SSI showed that as lowering this index, SSI would be lower and relative tolerance of genotypes to stress would be higher.

So, according this index under drought stress at flowering stage, KS12 and KR18 were identified as most tolerant and most sensitive genotypes (Table 2). Authors believe that a genotype with appropriate yield under favorable conditions must have good yield under undesirable conditions, so could introduce itself under drought stress conditions as proper cultivar, but lower SSI could not serve as strong reason for higher yield under proper or improper conditions. So that KS12 genotype by lowest SSI could not obtain highest yield (4016 kg/ha) and placed in second rank (Tables 1 and 2). According to SSI, Pod formation stage under stress conditions, KARAJ3 and HW101 genotypes were recognized as most tolerant and most sensitive genotypes under drought stress conditions, respectively (Table 2).

According to this index, higher tolerance is associated to a genotype which has lower index. Among studied genotypes at flowering stage under drought stress, KS12 with lowest TOL, had highest TOL amount and OPERA and KR18 genotypes had lowest stress tolerance at flowering stage (Table 1). Among studied genotypes, KARAJ3 genotype by lowest TOL most tolerant genotype and HW101 and OPERA genotypes had lowest drought stress tolerance at pod formation stage (Table 2).

If MP index is higher, relative tolerance to stress is higher, while Fernandez stated that this index is not proper for selection of high grain yield under drought stress conditions, because great difference in yield between both stress and non-stress conditions cause to increase this index, however KR4 and KS7 genotypes had more tolerance at both stress conditions than other genotypes at flowering stage under stress conditions and at pod formation stage at normal condition and KARAJ3 by medium MP index had average yield at both environmental conditions (Tables 1 and 2).

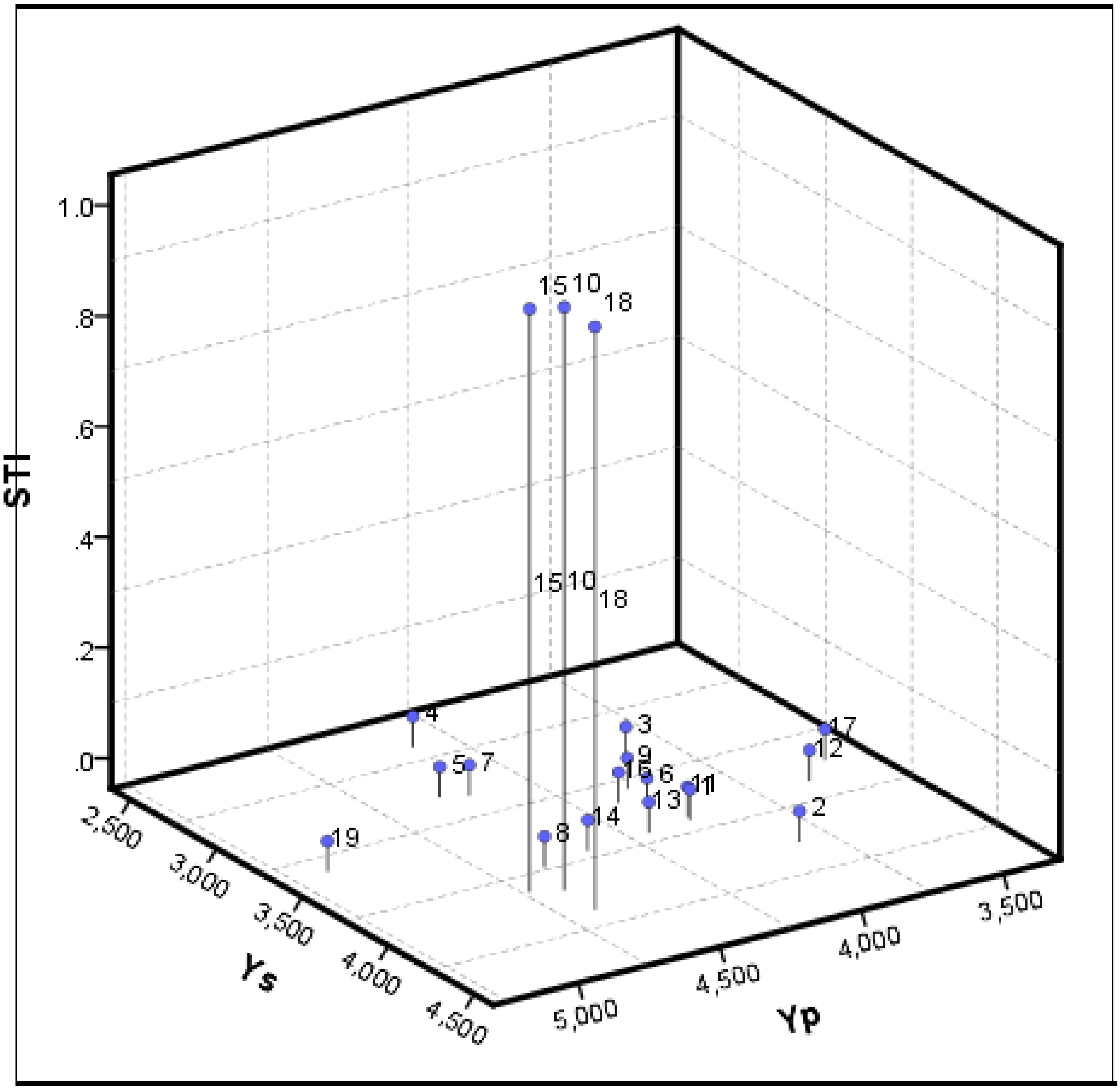
Highest and lowest MP index at pod formation stage respectively related to KR4 and KARAJ4 genotypes. KARAJ3 genotype by lowest MP index had mean yield at both environmental conditions (Figure 1). KR4 and KARAJ3 genotypes at flowering and pod formation stages under drought stress conditions showed similar results. By studying the geometric mean, it was determined that at pod formation stage highest and lowest GMP amount obtained in KR4 and KARAJ3 genotypes, respectively, and at flowering stage was related to KS7 and KR18, respectively (Figure 2).

Higher amount of STI for a genotype represents higher stress tolerance. Studying STI showed that at pod formation stage highest and lowest STI amount was related to KR4 and KARAJ3 genotypes and at flowering stage stress was related to KS7 and KR18, respectively. KR4 and KS7 showed similar trends at both stress conditions (Table 1). Highest and lowest yield at pod formation stage under stress condition was related to KR4 and HW101 genotypes and at flowering stage to KS7 and KR18 genotypes, respectively.

Table 1- canola genotype yield and stress tolerance indexes at flowering stage

		YP		YS		TOL		MP		SSI		GMP		STI	
G.N.	**Gen.**	**YP**	rank	**YS**	rank	**TOL**	rank	**MP**	rank	**SSI**	rank	**GMP**	rank	**STI**	rank
G1	***HW113***	4030	14	3662	8	368	4	3846	9	0.53	4	3841	9	0.81	9
G2	***KS12***	3858	17	4016	2	-157	1	3937	7	-0.23	1	3936	7	0.85	7
G3	***KARAJ1***	3918	16	3105	16	813	13	3512	18	1.20	15	3488	17	0.67	17
G4	***KR18***	4390	9	2644	19	1746	18	3517	17	2.31	19	3407	19	0.64	19
G5	***L73***	4540	6	3047	18	1493	17	3793	12	1.91	17	3719	13	0.76	13

G6	***L72***	4085	12	3504	11	581	8	3794	11	0.89	8	3783	11	0.79	11
G7	***HW101***	4460	7	3088	17	1372	16	3774	13	1.79	16	3711	14	0.76	14
G8	***L146***	4584	5	3729	5	855	15	4157	5	1.08	14	4134	5	0.93	5
G9	***L210***	4047	13	3326	15	721	12	3686	15	1.03	12	3668	15	0.74	15
G10	***L183***	4638	4	3932	3	706	9	4285	3	0.88	9	4270	3	1.00	3
G11	***SW101***	4024	15	3638	9	385	5	3831	10	0.55	5	3826	10	0.80	10
G12	***L5***	3571	18	3602	10	-21	3	3580	16	-0.05	3	3586	16	0.71	16
G13	***L201***	4184	10	3677	7	506	6	3930	8	0.70	7	3922	8	0.85	8
G14	***HW118***	4409	8	3693	6	715	10	4051	6	0.94	10	4035	6	0.89	6
G15	***KR4***	4729	2	3882	4	846	14	4305	2	1.04	13	4284	2	1.01	2
G16	***KARAJ2***	٤١٣٠,٠	11	3412	13	717	11	3771	14	1.01	11	3754	12	0.77	12
G17	***KARAJ3***	٣٤٤٤,٠	19	3482	12	-38	2	3463	19	-0.06	2	3462	18	0.66	18
G18	***KS7***	٤٦٤٦,٠	3	4125	1	520	7	4385	1	0.65	6	4378	1	1.05	1
G19	***OPERA***	٥١٣١,٠	1	3367	14	1763	19	4249	4	2.00	18	4156	4	0.95	4

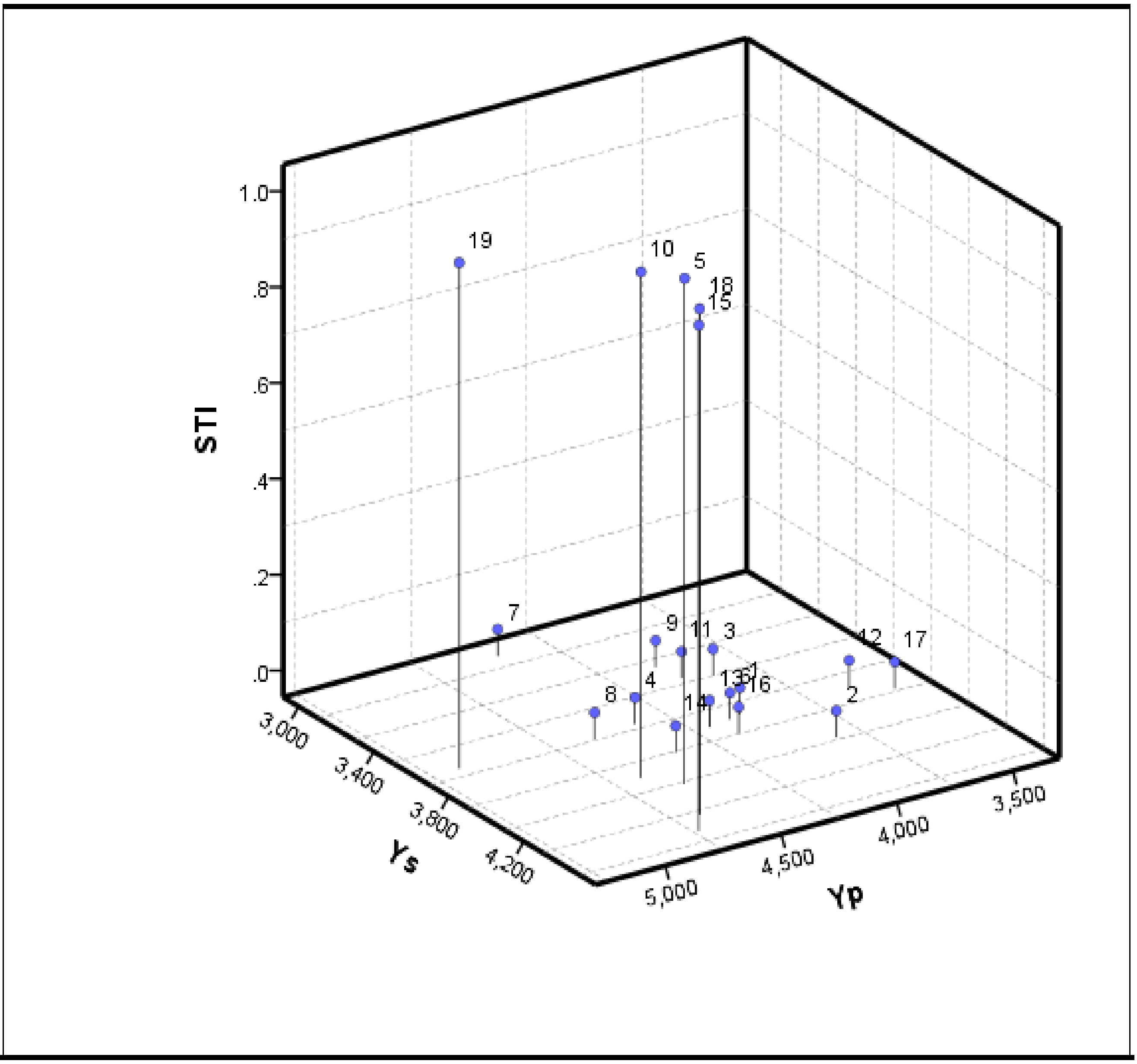


19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
OPERA	***KS7***	***KARAJ 3***	***KARAJ 2***	***KR4***	***HW118***	***L201***	***L5***	***SW101***	***L183***	***L210***	***L146***	***HW101***	***L72***	***L73***	***KR18***	***KARAJ 1***	***KS12***	***HW113***

Figure 1- simultaneous comparison of yield under normal and stress conditions at flowering stage by STI index

Table 2- canola genotype yield and stress tolerance indexes at pod forming stage

		YP		YS		TOL		MP		SSI		GMP		STI	
G.N.	**Gen.**	**YP**	rank	**YS**	rank	**TOL**	rank	**MP**	rank	**SSI**	rank	**GMP**	rank	**STI**	rank
G1	***HW113***	4030	14	3782	12	248	5	3906	13	0.57	5	3904	13	0.84	13
G2	***KS12***	3858	17	4084	4	-225	2	3971	11	-0.54	3	3969	11	0.87	11
G3	***KARAJ1***	3918	16	3501	16	417	10	3709	16	0.99	11	3703	15	0.75	15
G4	***KR18***	4390	9	3668	14	722	16	4029	8	1.54	15	4013	8	0.89	8
G5	***L73***	4540	6	4117	3	423	11	4238	4	0.87	10	4323	4	1.03	4
G6	***L72***	4085	12	3797	10	288	6	3941	12	0.66	8	3938	12	0.86	12
G7	***HW101***	4460	7	3023	19	1437	18	3741	15	3.02	19	3671	18	0.74	18
G8	***L146***	4584	5	3692	13	892	17	4138	7	1.82	17	4114	7	0.93	7
G9	***L210***	4047	13	3354	18	683	15	3700	17	1.60	16	3684	16	0.75	16
G10	***L183***	4638	4	4006	5	632	14	4322	5	1.27	13	4310	5	1.02	5
G11	***SW101***	4024	15	3464	17	560	13	3744	14	1.30	14	3733	14	0.77	14
G12	***L5***	3571	18	3797	11	-225	3	3684	18	-0.59	2	3682	17	0.74	17
G13	***L201***	4184	10	3811	9	373	9	3997	10	0.83	9	3993	10	0.88	10
G14	***HW118***	4409	8	3909	6	500	12	4159	6	1.06	12	4151	6	0.95	6
G15	***KR4***	4729	2	4427	1	302	7	4578	1	0.89	6	4575	1	1.15	1
G16	***KARAJ2***	4130	11	3899	7	231	4	4014	9	0.52	4	4012	9	0.88	9
G17	***KARAJ3***	3444	19	3884	8	-440	1	3664	19	-1.19	1	3657	19	0.73	19
G18	***KS7***	4644	3	4329	2	316	8	4487	2	0.63	7	4484	2	1.11	2
G19	***OPERA***	5131	1	3647	15	1484	19	4389	3	2.70	18	4325	3	1.03	3



19	**18**	**17**	**16**	**15**	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
OPERA	***KS7***	***KARAJ3***	***KARAJ2***	***KR4***	***HW118***	***L201***	***L5***	***SW101***	***L183***	***L210***	***L146***	***HW101***	***L72***	***L73***	***KR18***	***KARAJ1***	***KS12***	***HW113***

Figure 2- simultaneous comparison of yield under normal and stress conditions at pod forming stage by STI index

4. Conclusion

According to results from drought stress resistance (SSI), drought stress tolerance (TOL) at flowering stage, KS12 and at pod forming stage Karaj3 genotype was determined as superior genotypes. And according to MP, GMP and STI indices, KS7 and KR4 at flowering stage and KR4 and KS7 at pod forming stage, placed in first and second ranks by a little difference which were similar with SSI and TOL indices. L183 was recognized as stable genotype according to stability indices and using drought stress resistance indices this genotype was not identified as superior genotype and KS7, KR4, KS12 and KARAJ3 genotypes were recognized as most tolerant genotypes for drought stress and based on results from parametric statistics, KR4, KS7 and KARAJ3 genotypes were recognized as stable and drought stress tolerant genotypes.

References

Ashraf A. Abd El-Mohsen, M. A. Abd El-Shafi, E. M. S. Gheith, H. S. Suleiman. 2015. Using Different Statistical Procedures for Evaluating Drought Tolerance Indices of Bread Wheat Genotypes. Adv. Agric. Biol. 4 (1): 19-30.

Clarke JM, De Pauw RM, Townley-Smith TM.1992. Evaluation of methods for quantification of drought tolerance in wheat. Crop Sci., 32: 728-732.

Farshadfar E, Elyasi P, Aghaee M.2012. In Vitro selection for drought tolerance in common wheat (Triticum aestivum L.) genotypes by mature embryo culture, Americ. J. Sci. Res., 48: 102-115.

Farshadfar E, Elyasi P.2012. Screening quantitative indicators of drought tolerance in bread wheat (Triticum aestivum L.) landraces, Eur. J. of Exper. Biol., 2(3): 577-584.

Farshadfar, E., & Sutka, J. (2002). Multivariate analysis of drought tolerance in wheat substitution lines. Cereal Research Communication, 31, 33-39.

Fernandez GCJ. 1992. Effective selection criteria for assessing plant stress tolerance. In: Proc, of the Int. Symp. On adaptation of vegetables and other food crops in temperature and water stress. Tqiwan: 257-270.

Fischer AT, Maurer R.1978. Drought resistance in spring wheat cultivars. I. Grain yield responses. Aust. J. Agric. Res., 29: 897-912.

Gavuzzi P, Rizza F, Palumbo M, Campaline RG, Ricciardi GL, Borghi B. 1997. Evaluation of field and laboratory predictors of drought and heat tolerance in winter cereals. Can. J. Plant. Sci., 77: 523-531.

Golabadi M, Arzani A, Maibody M. 2006. Assessment of drought tolerance in segregating populations in durum wheat. African J. of Agric. Res., 1(5): 162-171.

Golestani -Araghi S, Assad MT.1998. Evaluation of four screening techniques for drought resistance and their relationship to yield reduction ratio in wheat. Euphytica, 103: 293-299.

Guttieri MJ, Stark JC, Brien KO, Souza E. 2001. Relative sensitivity of spring wheat grain yield and quality parameters to moisture deficit. Crop Sci., 41:327-335.

Johnson RA, Wichern DW.2007. Applied Multivariate Statistical Analysis (6thEd.). Prentice-Hall International, Englewood Cliffs, NJ, USA.

Khalili M, Naghavi MR, Pour Aboughadareh AR, Talebzadeh J.2012. Evaluating of Drought Stress Tolerance based on selection indices in spring canola cultivars (Brassica napus L.). JAS, 4(11):78-85.

Lan J. 1988. Comparison of evaluating methods for agronomic drought resistance in crops. Acta Agric. Boreali-occidentalis Sinica, 7: 85–87.

Majidi M, Tavakoli V, Mirlohi A, Sabzalian MR.2011. Wild safflower species (Carthamus oxyacanthus Bieb.): A possible source of drought tolerance for arid environments. Aust. J. Crop Sci., 5(8):1055-1063.

Rosielle AA, Hamblin J.1981. Theoretical aspect of selection for yield in stress and non-stress environment, Crop Sci., 21: 943-946.

Safavi S.M., Safavi A.Z., Safavi S.A. 2015. Evaluation of drought Tolerance in Sunflower (Helianthus annuus L.) Inbred Lines and Synthetic Varieties under Non Stress and Drought Stress Conditions. Biological Forum – An International Journal 7(1): 1849-1854.