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Effects of Water Deficit on Drought Tolerance Indices of Sesame (*Sesamum indicum* L.) Genotypes in Moghan Region

[1]M. Hassanzadeh, [2]A. Asghari, [1]Sh. Jamaati-e-Somarin, [1]M. Saeidi, [1]R. Zabihi-e-Mahmoodabad and [1]S. Hokmalipour
[1]Young Researchers Club, Department of Agronomy, Faculty of Agriculture, Islamic Azad University, Ardabil Branch, Ardabil, Iran
[2]Department of Agronomy and Plant Breeding, Faculty of Agriculture, University of Mohaghegh Ardabili, Ardabil, Iran

Abstract: In order to investigation of water deficit on drought tolerance indices of 27 sesame genotypes, a factorial experiment based on randomized complete block design was carried out in Moghan region in 2006 cropping year with three replications. Factors were: 27 sesame genotype (Karaj 1, Yekta, Oltan, Moghan 17, Naz takshakheh, Naz chandshakheh, Borazjan 2, Borazjan 5, Darab 14, Varamin 37, Varamin 237, Varamin 2822, Zoodrass IS, Hendi, Chini, Yellow white, 5089, Panama, DO-1, TF-3, TKG-21, J -1, RT-54, Hendi 9, Hendi 12, Hendi 14 and Jiroft) and irrigation (complete irrigation and irrigation until beginning of flowering). Results showed that Varamin 2822 genotype and Hendi 12 genotype in stress conditions had the highest yield stability about tolerance (TOL) and Mean Productivity (MP) indices, respectively. Regarding to Geometric Mean Productivity (GMP), Karaj 1, Oltan and Naz takshakheh were at highest level. Based on Stress Susceptibility Index (SSI), Varamin 237, Naz takshakheh, Naz chandshakheh, Oltan, Hendi 12, J-1, Panama genotypes and Jiroft line, were among mid-resistant and Zoodrass IS genotype was as sensitive one. Based on Stress Tolerance Index (STI), Varamin 2822, arranged as mid–resistant genotype. So, Karaj 1, Naz takshakheh, Varamin 237 and Varamin 2822 had highest rates (about mentioned indices) and are suitable for cropping under drought stress conditions.

Key words: Drought stress, sesame, TOL, MP, GMP, SSI, STI

INTRODUCTION

Sesame (*Sesamum indicum* L.) is one of the most ancient crop plants. This crop has been planted from olden times and this reason, the exact date of its being cultivation has not been defined yet. Today, the main usage of sesame depends on its favorite edible oil (Khajehpour, 2006). This plant has been adapted for planting in warm and arid regions and so, always has been confronted with water stress. Drought tolerance consists of ability of crop to growth and production under water deficit conditions. A long term drought stress effects on plant metabolic reactions associates with, plant growth stage, water storage capacity of soil and physiological aspects of plant. Drought tolerance in crop plants is different from wild plants. In case crop plant encounters severe water deficit, it dies or seriously loses yield while in wild plants their surviving under this conditions but no yield loss, is taken into consideration. However, because of water deficit in most arid regions, crop plants resistance against drought, has always been of great importance and has taken into account as one of the breeding factors (Alizadeh, 2004). One of the main aspects of plant tolerance is ability of plant cells to survey

Corresponding Author: Mohammad Hassanzadeh, Young Researchers Club, Department of Agronomy, Faculty of Agriculture, Islamic Azad University, Ardabil Branch, Ardabil, Iran
Tel: +989143528135

under severe water content lose without suffering sharp damages. While cell dries, usually vacuole crumples more than cell wall so, results in tearing protoplasm. It seems that such damages are the main reasons for cell death which has no tolerance mechanism (Lessani and Mojthaedi, 2002). Plant yield lose under insufficient water is an important issue for plant breeders and they tend to improve plant yield in this case but, difference in yield potential more relates to compatibility to stress factors So, drought tolerance indices are used to determine tolerant genotypes (Mitra, 2001). Rate and seasonal distribution of precipitation, temperature and soil conditions are the main factors affecting yield and yield components of sesame in arid and semi-arid areas (Nath and Chakrabotry, 2001). Sepaskhah and Andam (2001) determined sesame evapotranspiration in semi-arid conditions about 915 mm. In a study, it was illustrated that sesame seeds highly had the ability to germination in Poly Ethylene Glycol (PEG) solution compared to glucose and salt (Mensah *et al*., 2006). Rosielle and Hamblin (1981) defined tolerance index (TOL) as yield difference under stress (Ys) and non-stress or potential (Yp) conditions. Also, they determined Mean Productivity (MP) as mean production in stress and non-stress circumstances. Fischer and Maurer (1978) introduced Stress Susceptibility Index (SSI). Fernandez (1993) suggested another resistance criterion by the name of Stress Tolerance Index (STI) which to be used determining genotypes with high yields in both stress and normal conditions. Also, Ramirez Vallejo and Kelly (1998) defined Geometric Mean Productivity (GMP) which can be used rather then relative performance. Clarke *et al*. (1992) applied SSI in order to evaluating drought resistance in wheat cultivars. Guttieri *et al*. (2001) using SSI suggested that higher values than 1, indicates more sensitivity and lower ones indicate less sensitivity to water deficit stress. Ramirez Vallejo and Kelly (1998) demonstrated that GMP and SSI indices are mathematical derivatives of yield and cultivar selection based on both indices can be more appropriate criterion to assessment drought tolerance in bean. In wheat, SSI and grain yield indices have been used as plant resistance parameters and recognition of tolerant genotypes (Bansal and Sinha, 1991).

The aim of this study was investigation of effects of drought stress on drought tolerance indices of 27 sesame genotypes and evaluation of correlations between yield under stress and normal conditions and drought tolerance indices in order to selecting genotypes having high and stable yields under these conditions in Moghan region, Iran.

MATERIALS AND METHODS

In order to investigation of drought stress effect on drought tolerance indices of sesame genotypes in Moghan region, Iran, a factorial experiment based on randomized complete block design with three replications was laid out in 2006. First factor was 27 sesame genotypes (Karaj 1, Yekta, Oltan, Moghan 17, Naz takshakheh, Naz chandshakheh, Borazjan 2, Borazjan 5, Darab 14, Varamin 37, Varamin 237, Varamin 2822, Zoodrass IS, Hendi, Chini, Yellow white, 5089, Panama, DO-1, TF-3, TKG-21, J -1, RT-54, Hendi 9, Hendi 12, Hendi 14 and Jiroft) and second factor was irrigation levels: (complete irrigation and irrigation until flowering stage in 10-12 day intervals). The region was semi-arid with warm summers and moderate winters located at 39°39′ latitude and 47°18′ altitude. Based on soil test, organic carbon rate was 1.75%, phosphorus of 7 mg kg^{-1}, potassium of 700 mg kg^{-1} and soil salinity was <2 dm m^{-2}. Crop was planted on July 2006. Each genotype was sown in four 4 m rows spaced 60 cm apart. Distance of plants in rows was 4 cm in depth of 1-2 cm. The rate of 50 kg ha^{-1} nitrogen and phosphorus was applied before planting as soil incorporation. 100 kg ha^{-1} nitrogen was applied during the season, as well. In order to determination yield, plants of two middle rows of each plot were harvested and transferred to laboratory. By the way, genotypes were classified based on the rate of yield using cluster analysis (Fig. 1) into three distinct groups (data not shown). SSI was calculated according to Fischer and Maurer (1978):

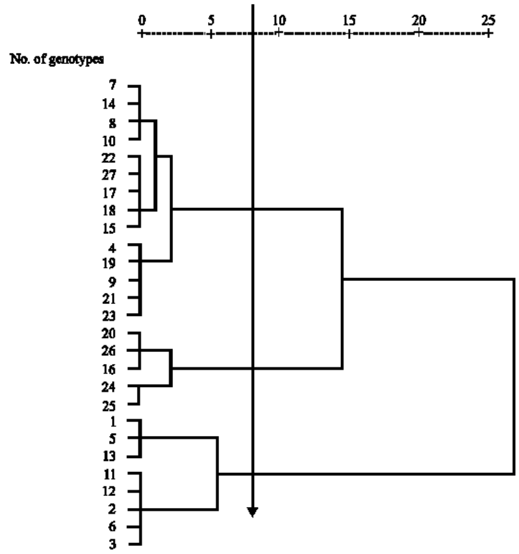

Fig. 1: Dendrogram of classified genotypes using cluster analysis

$$SSI = [1-(Ysi/Ypi)]/SI \text{ and } SI=1-(Ys/Yp)$$

Where:
Ypi = Genotype yield in non-stress conditions
Ysi = Genotype yield in stress conditions
Ys = Mean yield of all genotypes in stress conditions
Yp = Mean yield of all genotypes yield in non-stress conditions

Lower SSI meaning higher drought tolerance. STI and TOL were calculated according to Fernandez (1993):

$$STI = (Ypi)(Ysi)/(Ypi)^2 \text{ and } TOL = (Ypi-Ysi)$$

GMP and MP were calculated as follows:

$$GMP = \sqrt{(Ysi)(Ypi)} \text{ and } MP = (Ysi+Ypi)/2$$

Data were subjected to analysis using SAS and SPSS and graphs were drawn using EXCEL softwares. Mean comparisons were done with Duncan's multiple range test.

RESULTS AND DISCUSSION

Drought Tolerance Indices

In non-stress, the most Ypi was gained of 952.5, 949.6, 934.2 and 1003.2 kg ha^{-1} for Karaj 1, Naz takshakheh, Varamin 237 and Oltan genotypes, respectively (Table 1). Also, in stress, the most Ysi was gained of 789.3 and 769.9 kg ha^{-1} for Karaj1 and Naz takshakheh, respectively. Drought tolerance is a complicated objective and different factors affect on it. So, judgment about one trait is different and sometimes including contradictory results. For this purpose, using the analysis of correlation between

Table 1: Drought tolerance indices for studied genotypes

Genotypes	Ypi	Ysi	TOL	MP	STI	GMP	SSI
High yielding genotypes							
Karaj 1	952.5	789.3	163.20	870.90	0.828	867.06	1.103
Yekta	887.2	646.4	240.80	766.80	0.728	757.28	1.000
Oltan	1003.2	686.4	316.80	844.80	0.684	829.81	0.927
Zoodrass IS	740.5	504.8	235.70	622.65	0.681	611.39	2.287
Naz takshakheh	949.6	769.9	179.70	859.75	0.810	855.04	0.999
Naz chandshakheh	822.9	647.5	175.40	735.20	0.786	729.95	0.999
Varamin 237	934.4	609.6	324.80	772.00	0.652	754.72	0.885
Varamin 2822	685.1	614.1	71.00	649.60	0.896	648.62	1.000
Medium yielding genotypes							
Moghan 17	706.4	394.4	312.00	550.40	0.558	527.82	1.000
Varamin 37	668.5	544.5	124.00	606.50	0.814	603.32	1.000
Borazjan 2	820.0	534.7	285.30	677.35	0.652	662.15	1.036
Borazjan 5	670.7	524.8	145.90	597.75	0.782	593.28	1.000
Darab 14	585.2	427.2	160.00	507.20	0.727	500.85	1.000
Hendi	637.9	535.7	102.20	586.80	0.839	854.57	1.000
Chini	678.7	468.8	209.90	573.75	0.690	564.06	1.000
Jiroft	598.1	459.2	138.90	528.65	0.767	524.06	0.999
5089	689.1	472.0	217.10	580.55	0.684	570.31	1.000
Panama	582.9	492.8	90.10	537.85	0.845	535.96	0.999
DO-1	580.0	382.4	197.60	481.20	0.659	470.94	1.000
RT-54	628.8	408.5	220.30	518.65	0.649	506.81	1.000
TKG-21	750.7	423.2	327.50	586.95	0.563	563.64	1.000
J-1	650.4	466.7	183.70	558.55	0.717	550.94	0.999
Low yielding genotypes							
TF-3	764.3	267.2	497.10	515.75	0.349	451.90	1.000
Hendi 9	404.0	197.3	206.70	300.65	0.488	282.32	1.000
Hendi 12	277.9	158.7	119.20	218.30	0.571	210.00	0.999
Hendi 14	429.1	270.1	156.00	349.60	0.629	340.44	1.000
Yellow white	558.4	311.2	247.20	434.80	0.557	416.86	1.000

yields under stress and non-stress conditions and quantitative drought tolerance indices, superior indices and consequently genotypes, were selected. Generally, indices having high correlation's with plant yield in stress and non-stress conditions, are introduced as the best ones because, they can separate genotypes with high yields in both conditions (Fernandez, 1993). In soybean, Sneller and Dombek (1997) reported that selection in irrigated trials, would improve yield of stress, better than non-irrigated trials. Genotypes with high TOL values are sensitive to stress and selection must be done based on low rates of this index. Varamin 2822 and Panama genotypes from this view had the yield stability among the other genotypes. Ramirez and Kelly (1998) used low values of TOL in order to selecting drought resistant genotypes. Using MP and TOL indices, it can be separated genotypes producing high yields solely in non-stress conditions from the genotypes with the same yields in stress conditions (Rosielle and Hamblin, 1981). So, it seems that application of these indices is not suitable for selecting superior genotypes. Karaj1 genotype had the highest MP value and hence, had the highest Ypi. Fernandez (1993) suggested MP and STI indices to select the most resistant cultivars of bean against drought. Based on GMP, genotypes of Karaj 1, Oltan and Naz takshakheh had the most values of 867.06, 829.81 and 855.04, so, could be classified as genotypes with high yields under the both conditions. Lower values of SSI indicate low yield changes under stress and non-stress environments and demonstrate more yield stability. Using this index, genotypes with high yields in both conditions could be separated (Fischer and Maurer, 1978). From this view, Karaj 1, Yekta, Moghan 17, Chini, Yellow White, RT-54, Hendi 9, Borazgan 2, Borazgan 5, Darab 14, 5084, Do-1, Hendi 14, Varamin 37, Varamin 2822, Hendi, TF-3 and TKG-21 genotypes were including mid-sensitive ones and Zoodrass IS genotype was categorized as sensitive one. According to Fernandez (1993), more stable genotypes have higher rates of STI. Using this index, genotypes having remarkable yields under stress and non-stress environments could be recognized. Based on this index, Varamin 2822 genotype was classified as mid-resistant one.

Table 2: Correlations between drought tolerance indices with Ypi and Ysi

Traits	Ypi	Ysi	TOL	MP	STI	GMP	SSI
Ysi	0.86**	1.00					
TOL	0.39*	-0.11^{ns}	1.00				
MP	0.96**	0.96**	0.15^{ns}	1.00			
STI	0.28^{ns}	0.70**	-0.74**	0.50**	1.00		
GMP	0.95**	0.97**	0.09^{ns}	0.99**	0.55**	1.00	
SSI	0.32^{ns}	0.35*	-0.02^{ns}	0.35*	0.16^{ns}	0.35*	1.00

^{ns}: Non significant, *,**; Significant at $p<0.01$ and $p<0.05$, respectively

Correlation Coefficients

Correlation coefficients between drought tolerance indices with Ypi and Ysi (Table 2) showed that Ypi had significant and positive correlation with MP. Also, Ysi had significant and positive correlation with MP and SSI which was completely in accordance with Fernandez (1993). Ypi had the significant and positive correlation with GMP and TOL, as well. Ypi and Ysi had significant and positive correlation with GMP and results of Ramirez *et al*. (1998) confirmed this matter. Ysi with STI, GMP and STI had negative and significant correlation which is in agreement with Golabadi *et al*. (2006). Also, MP with STI, GMP and SSI and GMP with SSI had significant and positive correlation. Generally, it can be said that Varamin 2822 among high-yielding genotypes has the least difference between stress and non-stress yields and has the yield stability in both conditions. Likewise, Oltan, Naz takshakheh, Naz chandshakheh and Varamin 237 had the least SSI and the most yields in non-stress conditions but their yield reduction in stress conditions is not too much to preventing their planting in non-irrigated conditions.

CONCLUSION

According to the results, the highest yield in non-stress conditions was obtained for Karaj1, Naz takshakheh, Varamin 237 and Oltan and in stress conditions was obtained for karaj1 and Naz takshakheh genotypes. Based on TOL and STI indices, Varamin 2822, Karaj1, Naz takshakheh and based on SSI index, Varamin 237 genotypes were of tolerant genotypes under drought conditions and so, are suitable for planting under mentioned conditions.

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