African Journal of Agricultural Research Vol. 7(18), pp. 2879-2883, 12 May, 2012
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.1324
ISSN 1991-637X ©2012 Academic Journals

Full Length Research Paper

Study of drought stress effect on some traits of lentil cultivars and the correlations between them

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Accepted 17th April, 2012

Drought stress, which has a great impact on agricultural and forestry production and often causes yield reduction, is one of the most important agricultural research topics, therefore, in order to assess drought tolerance in lentil cultivars Ardabil region, a factorial experiment based on randomized complete block design with three replications in the 2010 Farm Agricultural Research Station University, Ardebil, was performed. Factors used included two levels of planting conditions (irrigation and non-irrigation) and five lentil cultivars. Results showed that, yield loss of the ILL 1180 under stress was about 23.31% more than normal conditions. This value for the ILL 1324 ranged approximately 35.51%. Also, ILL 1180 showed the lowest tolerance against stress and stress susceptibility index and the highest mean productivity, geometric mean productivity and stress tolerance index indices. ILL 1324 possessed the highest TOL (tolerance index), SSI (stress susceptibility index) and STI (stress tolerance index) and ILL 1237 showed the lowest MP (mean productivity) and GMP (geometric mean productivity) indices, and as such, ILL 1180 and ILL 1251 were the superior cultivars under both conditions in terms of high yield and tolerance against drought stress. ILL 1237 was distinguished as the most susceptible cultivar as well.

Key words: Drought stress, cultivar, yield, lentil.

INTRODUCTION

Environmental stress such as water limitation during growth and development of plants can affect subsequent seed quality (Younesi and Moradi, 2009). Drought stress, which has a great impact on agricultural and forestry production and often causes yield reduction, is one of the most important agricultural research topics (Zhang et al., 2008). The effect of drought stress is a function of genotype, intensity and duration of stress, weather conditions, growth and developmental stages of rape seed (Robertson and Holland, 2004). The effects of water stress depend on the timing, duration, and magnitude of water deficiency (Pandey et al., 2001). The occurrence time is more important than the water stress intensity (Korte et al., 1983).

Yield loss of the plants under water deficit is one of the most important events for the plant breeders to improve yield but difference in the yield potential mainly relates to the adaptation factors than merely to the stress itself and as a result, drought tolerance indices were used to determine resistant genotypes (Mitra, 2001). Rate seasonal distribution of precipitation, temperature difference and soil conditions are important factors affecting yield and yield components of sesame in the arid and semi-arid regions (Nath and Chakrabotary, 2001). Rosielle and Hamblin (1981) introduced tolerance against stress (TOL) as yield difference between stress (Ys) and non-stress (Yp). Based on their definitions, mean yield under stress and non-stress is called mean productivity (MP). An index named stress susceptibility index (SSI) was developed by Fischer and Maurer (1978). Also, stress tolerance index (STI) was introduced by Fernandez (1992) to determine genotypes having yields under both stress and normal conditions. Clarke et al. (1992) used SSI to determine tolerance against drought. Guttieri et al. (2001), using SSI, suggested that the rates higher than 1, indicates more susceptibility to stress and rates lower than 1, indicates less susceptibility.

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Table 1. Drought tolerance Indices of cultivars studied.

Cultivars	Ypi	Ysi	SSI	TOL	STI	GMP	MP
ILL1324	1321.75	1013.53	0.75	308.22	0.81	1157.42	1167.64
ILL1237	1262.96	814.43	1.15	448.53	0.62	1014.20	1038.7
Native variety	1329	940.26	0.95	388.73	0.76	1117.86	1134.63
ILL1180	1279.76	844.63	1.104	435.13	0.65	1039.67	1062.2
ILL1251	1207.16	818.26	1.04	388.9	0.602	993.87	1012.71

Yield rates under stress (Ysi) and optimum (Ypi) conditions, tolerance index (TOL), stress susceptibility index (SSI), mean productivity (MP), geometric mean productivity (GMP) and stress tolerance index (STI).

Breeding for drought tolerance is complicated by the lack of fast reproducible screening techniques and the inability to routinely create defined and repeatable water stress conditions when a large amount of genotypes can be evaluated efficiently (Ramirez and Kelly, 1998). Achieving a genetic increase in yield under these environments has been recognized to be a difficult challenge for plant breeders while progress in yield grain has been much higher in favorable environments (Richards et al., 2002). Water limitation during seed development usually interrupts development and results in small seed size (Cruz-Aguado et al., 2000). The reduction in seed size is due primarily to a shortening of the filling period rather than an inhibition of seed growth rate (Vieira et al., 1992). Drought reduces biomass and seed yield, harvest index, number of silique and seeds, seed weight, and days to maturity (Abebe and Brick, 2003; Munoz-Perea et al., 2006; Padilla-Ramirez et al., 2005). Moreover, drought increases cooking time and seed protein content on dry weight basis (Frahm et al., 2004).

The aim of this study was to determine the most suitable lentil cultivars against drought stress, measuring the different drought tolerance indices, and determining the most resistant and susceptible cultivars under drought conditions.

MATERIALS AND METHODS

In order to evaluate drought tolerance, indices of lentil cultivars, a factorial experiment based on randomized complete block design with three replications was arranged at the Agricultural Research Station of the Islamic Azad University, Ardabil branch, Ardabil, Iran in 2010. Ardabil has cool winters and moderate springs and summers (38° 15' N, 48° 15' E) with an average annual precipitation of 400 and 1350 m height from sea level. Factors included two conditions of planting levels (irrigated and non-irrigated) and five lentil cultivars (ILL 1180, ILL 1324, ILL 1251, ILL 1237 and native cultivar). Experimental plots contained 5 cropping lines, 25 cm apart, and each 4 m. It was assigned 0.5 m distance between the two plots as boarder effect; distance between blocks was determined as 2 m. Final plant population was set at 133 plant/m^2 and grown at a depth of 3 to 5 cm. The field was under fallow last year. Soil preparation included deep plough, disc harrow and soil leveling. To supply for required elements, 40 kg/ha zinc sulfate, 100 kg/ha superphosphate and 20 t/ha manure was applied to the soil based on soil test.

Drought tolerance indices

SSI was calculated based on Fischer and Maurer (1978):

SSI = [1- (Ysi/Ypi)]/SI and SI = 1- (Ys/Yp)

Where, Ypi = Yield of individual cultivars without stress, Ysi=yield of individual cultivars with stress, Ys= average yield of all cultivars with stress, Yp= average yield of all cultivars without stress.

Lower SSI rates refer to higher drought tolerance. STI and TOL indices were calculated as Fernandez (1992):

STI = (Ypi) (Ysi) / $(Yp)^2$ and TOL = (Ypi-Ysi)

Higher rates for the STI, indicates higher potential yield. Also, GMP and MP were calculated as follows:

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

Statistical analysis

Data were subjected to analysis by SPSS and MINITAB software.

RESULTS AND DISCUSSION

Drought tolerance indices

Yield rates under stress (Ysi) and optimum (Ypi) conditions, and other drought tolerance indices are shown in Table 1. According to the dendrogram derived from the cluster analysis based on the rain fed conditions (Figure 1), it was illustrated that ILL 1180 and ILL 1251 cultivars were of high yields in the same group and the rest, placed in the second group whereas, the aforementioned cultivars gained the highest yields in both conditions. As with the tolerance index (TOL), higher values indicate susceptibility of the given cultivar, and as a result, selection was performed based on the lower rates of this index. According to this, ILL 1324 had the lowest TOL (the most resistant) while, ILL 1324 showed the highest value (the most susceptible). Also, for the mean productivity (MP), it was found that ILL 1180 had the highest rate and in contrast, ILL 1237 possessed the lowest rate. Separation of cultivars was solely on the basis of having high yields in normal conditions from those having optimum yields under stress which is

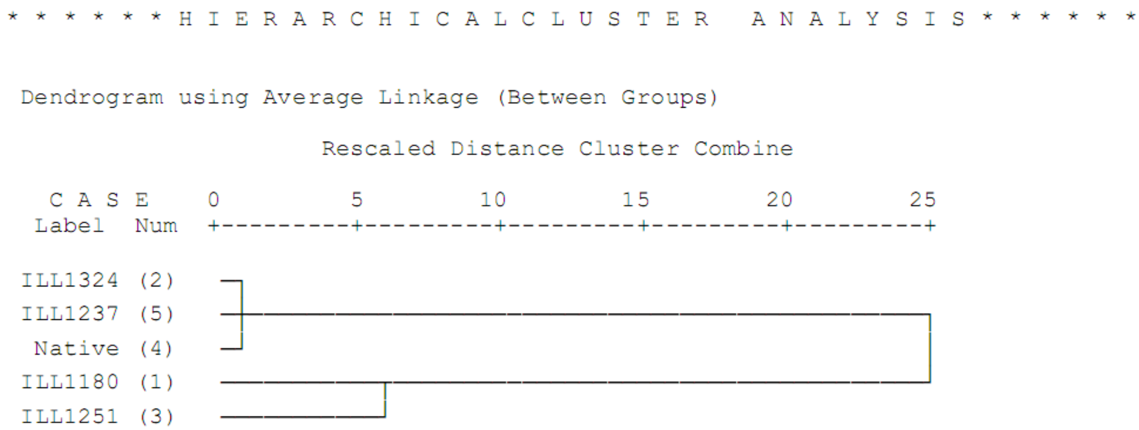

Figure 1. Dendrogram based on the yield of lentil cultivars under planting conditions.

Table 2. Correlations: Ypi, Ysi, SSI, TOL, STI, GMP and MP.

Variable	Ypi	Ysi	SSI	TOL	STI	GMP
Ysi	0.819					
	0.090					
SSI	-0.589	-0.946				
	0.296	0.015				
TOL	-0.406	-0.857	0.978			
	0.497	0.063	0.004			
STI	0.888	0.990	-0.893	-0.779		
	0.044	0.001	0.041	0.120		
GMP	0.904	0.985	-0.878	-0.757	0.999	
	0.035	0.002	0.050	0.138	0.000	
MP	0.924	0.976	-0.854	-0.725	0.996	0.999
	0.025	0.004	0.066	0.165	0.000	0.000

Cell contents: Pearson correlation, P-value.

available using MP and TOL indices (Rosielle and Hamblin, 1981). It was found that ILL 1324 and ILL 1251 cultivars show the highest and lowest GMP.

Lowest rate of the stress susceptibility index (SSI) indicates low differences in the yield across the stress and normal conditions and hence, it is more of sustainability. Cultivars having the high yields under both stress and normal conditions are distinguished by this index (Fischer and Maurer, 1978). Based on the SSI index, it was seen that ILL 1324 and native had the lowest rate and in contrast, ILL 1237 possessed the highest one. Guttieri et al. (2001) suggested that the values higher than 1, indicate more susceptibility while the lower rates, illustrate more susceptibility. Ramirez and Kelly (1998) reported that GMP and SSI indices are mathematical derivatives of the yield data and selection based on the combination of both indices can be a more suitable criterion for assessment of the plant drought tolerance. It was seen that ILL 1180 and ILL 1251 had the highest rates, and ILL 1237 and ILL 1324 had the lowest values of the STI. Fernandez (1992) suggested that the more sustainable cultivars have the highest range of this index, distinguishing of the high yielding cultivars under both stress and normal condition is possible.

According to Table 2, Ypi have a positive and significant correlation with Ysi, STI, GMP and MP. Ysi have a positive and significant correlation whit STI, GMP

Table 3. Principal components analysis for indices.

Indices	PC1	PC2
Y_{Pi}	0.339	0.605
Y_S	0.400	-0.055
SSI	-0375	0.402
TOL	-0.333	0.632
STI	0.399	0.120
GMP	0.398	0.138
MP	0.395	0.191
% variance	88.9	11.01
Calamities variance%	88.9	99.9

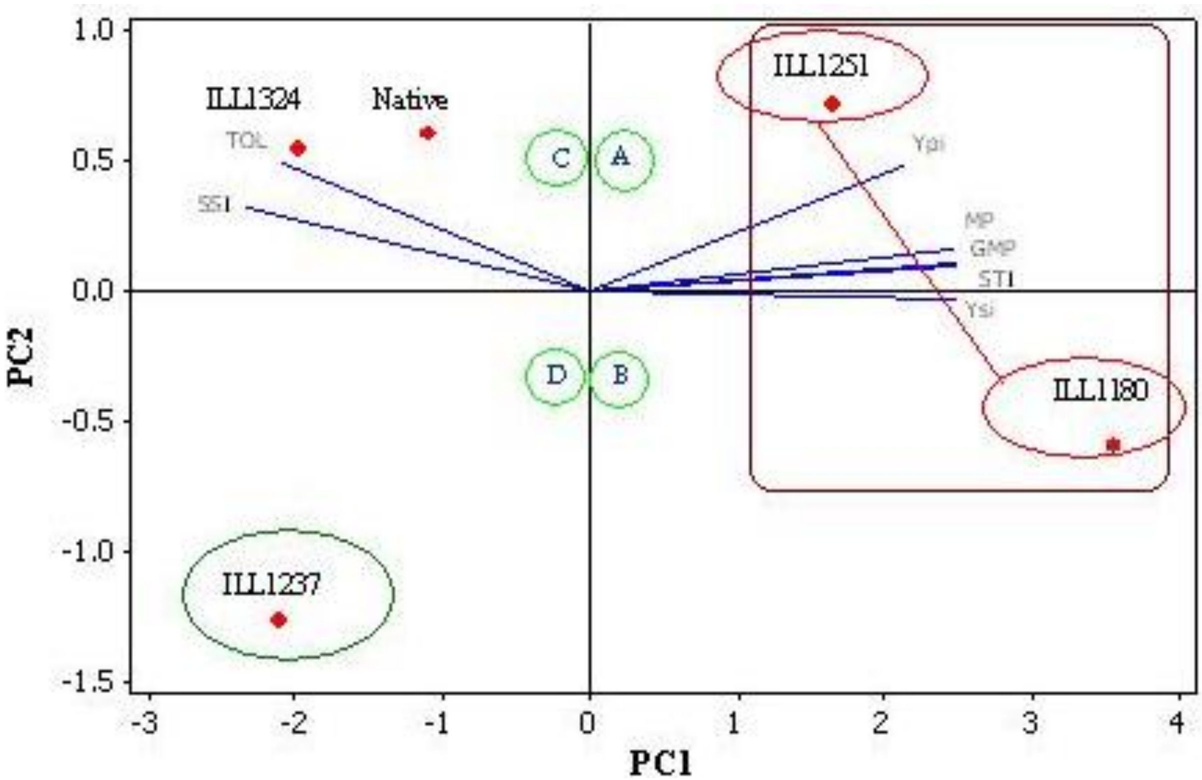

Figure 2. Biplot of the lentil cultivars for drought tolerance indices, under irrigation and non-irrigation conditions.

and MP and negative and significant correlation with SSI and TOL. SSI has a positive and significant correlation whit TOL and has a negative and significant correlation whit STI, GMP and MP. TOL has a negative and significant correlation whit STI, GMP and MP. STI have a positive and significant correlation with GMP and MP and finally, GMP has a positive and significant correlation whit MP index. Considering that 99.9% of the changes can be interpreted by the first two components and removal of other components did not affect the changes, drawing Biplot based on the two components was performed. The first component, 88.9% of the changes is justified and the second component of 11.01% of the change was justified (Table 3). Accordingly, the two separate groups of components within the cultivars were placed on biplot graphs and plotted based on the amount of performance and stress tolerance (Figure 2). Based on the first two components, biplot diagram was divided into four parts. Cultivars that were in the region with the highest yield were analyzed on both conditions. On the other hand, cultivars in group D had the lowest performance in both conditions. Accordingly, ILL1180 and ILL1251 as the most tolerant cultivars and ILL1237 as the less tolerant cultivar were used as sensitive groups A and D. Indices that were highly correlated with yield under stress had normal function and the angle between the normal and stress conditions were also superior as indicators were introduced. These indicators include GMP, MP, and had STI. The results of Moghaddam and Hadizadeh (2002) fully confirm their MP which showed that the selection index cultivars are more tolerant to stress than SSI and TOL indices.

Conclusion

In general, it was found that the yield loss of the following cultivars under rain-fed conditions included: ILL1180 of 435.14 kg ha^{-1} (36.03%), ILL 1324 of 448.53 kg ha^{-1} (35.51%), ILL 1251 of 388.74 kg ha^{-1} (29.25%), native cultivar of 435.13 kg ha^{-1} (34.00%), and ILL 1237 of 388.90 kg ha^{-1} (32.21%) (Table 1). Also, ILL 1180 had the lowest TOL and SSI and the highest MP, GMP and STI. The highest rates of the TOL, SSI and STI belonged to ILL 1324 and ILL 1237 which have the lowest MP and GMP. Since the highest yield under stress and normal conditions belonged to ILL 1180, and since it has the lowest yield loss under stress and the highest drought tolerance as with the various indices, it can be considered as the superior cv. and ILL 1237 as the most susceptible one.

REFERENCES

Abebe AS, Brick MA (2003). Traits associated with dry edible bean (*Phaseolus vulgaris* L.) productivity under diverse soil moisture environments. Euphytica, 133: 339-347.

Clarke JM, DePauw RM, Townley-Smith TF (1992). Evaluation of methods for quantification of drought tolerance in wheat. Crop. Sci., 32: 423-428.

Cruz-Aguado J, Rodes R, Perez I, Dorado M (2000). Morphological characteristics and yield components associated with accumulation and loss of dry mass in the internode of wheat. Field Crop Res., 66: 129-139.

Fernandez GCJ (1992). Effective selection criteria for assessing plant stress tolerance. In: Proceeding of Symposium. Taiwan, 13-16 Aug. Chapter, 25: 257-270.

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

Frahm MA, Rosas JC, Mayek-Perez N, Lopez-Salinas E, Acosta-Gallegos JA, Kelly JD (2004). Breeding beans for tolerance to terminal drought in the lowland tropics. Euphytica, 136: 223-232.

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

Korte LL, Williams JH, Specht JE, Sorenson RC (1983). Irrigation of soybean genotypes during reproductive ontogeny: II. Yield component responses. Crop Sci., 23: 528-533.

Mitra J (2001). Genetics and genetic improvement of drought resistance in crop plants. Curr. Sci., 80: 758-762.

Moghaddam A, Hadizadeh MH (2002). Response of corn cultivars and their parental lines to drought using different stress tolerant indices. Iranian. J. Seed. Seedling, 18: 255-272.

Munoz-Perea CG, Teran H, Allen RG, Wright JL, Westermann DT, Singh SP (2006). Selection for drought tolerance in dry bean landraces and cultivars. Crop Sci., 46: 2111-2120.

Nath PK, Chakrabotry A (2001). Effect of climatic variations on yield of sesame (*Sesamum indicum* L.) at different date of sowing. Agro. J. Crop Sci., 186: 97-102.

Padilla-Ramirez JS, Acosta-Gallegos JA, Acosta-Diaz E, Mayek-Perez N, Kelly JD (2005). Partitioning and partitioning rate to seed yield in drought-stressed and non-stressed dry bean genotypes. Annu. Rep. Bean Improve. Coop., 48: 152-153.

Pandey RK, Maranville JW, Admou A (2001). Tropical wheat response to irrigation and nitrogen in a Sahelian environment. I. Grain yield, yield components and water use efficiency. Eur. J. Agro., 15(2): 93-105.

Ramirez P, Kelly JD (1998). Traits related to drought tolerance in common bean. Euphytica, 99: 127-136.

Richards RA, Rebetzke GJ, Condon AG, Herwaarden AF (2002). Breeding opportunities for increasing the efficiency of water use and crop yield in temperate cereals. Crop Sci., 42: 111-121.

Robertson MJ, Holland JF (2004). Production risk of canola in the semi-arid subtropics of Australia. Aust. J. Agr. Res., 55: 525-538.

Rosielle AA, Hamblin J (1981). Theoretical aspects of selection for yield stress and non–stress environments. Crop Sci., 21: 943-946.

Vieira RD, Tekrony DM, Egli DB (1992). Effect of drought stress and defoliation in the field on soybean seed germination and vigor. Crop Sci., 32: 471-475.

Younesi O, Moradi A (2009). The Effect of Water Limitation in the Field on Sorghum Seed Germination and Vigor. Aust. J. Basic Appl. Sci., 3(2): 1156-1159.

Zhang WX, Zhao Z, Bai G.X, Fu FJ (2008). Study and evaluation of drought tolerance of different genotype maize inbred lines. Frontiers Agr. China, 2(4):428-434.