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Full Length Research Paper

Selection of resistance and sensitive cultivars of lentil in Ardabil region of Iran under irrigation and non-irrigation conditions

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In order to evaluate drought tolerance indices of lentil cultivars in the Ardabil region, a factorial experiment based on randomized complete block design with three replications was arranged at the Agricultural Research Station of Islamic Azad University, Ardabil branch, Ardabil, Iran, in 2010. The factors included two conditions of planting levels (irrigation and non-irrigation) and five lentil cultivars (ILL 1180, ILL 1324, ILL 1251, ILL1237, and native cultivars). Irrigation included complete irrigation from planting until maturity and non-irrigation from seed emergence until harvesting. The results showed that the length of vegetative and reproductive periods, total number of pod and seed per plant, 100-seed weight, seed yield and harvest index were of higher rates under irrigation than the stress (non-irrigation). Also, it was found that ILL 1180 and ILL 1324 cultivars possessed the highest and lowest values for all traits, respectively. Yield loss of the ILL 1180 under stress, was about 308.22 kg/ha (23.31%) than the normal conditions. This value for the ILL 1324 was approximately 448.53 kg/ha (35.51%). Also, ILL 1180 showed the lowest tolerance against stress (TOL) and stress susceptibility index (SSI) and the highest mean productivity (MP), geometric mean productivity (GMP) and stress tolerance index (STI) indices. ILL 1324 possessed the highest TOL, SSI and STI and ILL1237 showed the lowest MP and GMP indices. So, ILL1180 and ILL1251 were the superior cultivars under both conditions in terms of high yield and tolerance against drought stress. ILL1237 was distinguished as the most susceptible cultivar as well.

Key words: Lentil, yield, normal and stress conditions, drought tolerance index.

INTRODUCTION

Lentil is well adapted to the regions of precipitations lower than 400 mm, where the cultivation of wheat is common (Koochaki and Sarmavnia, 2002). Complementary irrigation enhances seed yield as the plant goes into the maturity stage (Amin et al., 2004). Since, the lentil is of in-determinate growth, supplying available water may result in higher vegetative and reproductive growth periods and drought stress during the flowering stage which decreases this period (Kusmenglu and Muehlbauer, 1998). Seed legumes usually gain various yields from year to year and water deficit is the main factors affecting this attribute (Ferguson et al., 1998).

Water deficit highly influences seed yield components and causes reduced pods per plant, seeds per pod and 100-seed weight. Hudak and Patterson (1995) showed that irrigation during seed filling period, improves yield. Also, in another work, it was reported that three times irrigations during seed filling period, increased the lentil yield (Eskine and Ashkar, 1993). Water deficit results in the decline of number of flowers, pods, seeds per pod, and size of pods and seed weight (Desclaus et al., 2000). Stress appearance during the reproductive stage, reduces seed weight (Katerji et al., 2000). The amount of the yield loss depends on the stress range and plant growth stage at which stress occurred. In fact, plant susceptibility to stress varies from germination to the maturity (Schmidtke et al., 2004).

One of the main drought resistance factors in plants is the ability of cells to tolerate a large amount of lost water

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without serious un-repairable damages. As the cell losses water, vacuole usually crumples more than cell wall which causes the silt in the protoplasm. It seems that such damage, results in the death of cells (Lessani and Mojtahedi, 2003). 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 in which drought resistance indices are used to determine resistant genotypes (Mitra, 2001). Rate seasonal distribution of precipitation, temperature difference and soil conditions are of 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 resistance against drought. Guttieri et al. (2001), using SSI, suggested that the rates higher than 1, indicate more susceptibility to stress and rates lower than 1, indicate less susceptibility. Ramirez and Kelly (1998) reported that GM and SSI indices are mathematical derivatives of yield data and selection based on the combination of both indices, may be suitable criterion for drought resistance assessment. SSI and seed yield indices are used as the plant sustainability parameters and distinguishing resistance genotypes under drought conditions (Sinha and Bansal, 1988). Fredrick et al. (2001) found that drought stress has no effect on the seed yield of the main stem of the determinate soybean however, this is a main part of the total yield. Also, they realized that the ratio of seed yield of the main stem to the total seed yield was low in the stress conditions than normal (irrigated). In this condition, harvest index of the main stems was low for the irrigated soybeans. They illustrated that the number of main stems and seeds per main stem was not affected by drought stress. In addition, correlation between seed yield of the main stem and weight of the individual seeds per main stem was insignificant. Desclaus (2000) and Foroud (1993) reported that water deficit results in the decrease in the number of flowers, pods, seeds per pod, pod size and seed weight.

The aims of this work were to determine the most suitable lentil cultivars against drought stress, measure the different drought resistance indices, and determine the most resistant and susceptible cultivars under drought conditions.

MATERIALS AND METHODS

In order to evaluate drought resistance 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 mm and 1350 m height from sea level. The 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 five 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. The final plant population was set as 133 plant/m^2 grown at a depth of 3 to 5 cm in the field which was under fallow last year. Soil preparation included deep plough, disc harrow and soil leveling. To supply the 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.

Phenological traits

These included the vegetative and reproductive growth stages.

Yield and yield components

After complete filling of the seeds, while the leaves and stems became yellow, two side rows were removed and sampling was done from three middle rows by deleting 0.5 m distance from both sides of them. The rest of the plants were harvested after ripening, seeds were air-dried and the following traits were measured: i) total seed weight; ii) total number of pods per plant; iii) number of seeds per plant; iv) harvest index; v) 100-seed weight; and vi) seed yield per unit area.

Drought resistance indices

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

$$SSI = [1-(Ysi/Ypi)]/SI,$$

$$SI = 1-(Ys/Yp)$$

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

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

$$STI = (Ypi)\ (Ysi) / (Yp)^2$$

$$TOL = (Ypi-Ysi)$$

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

$$GMP = \sqrt{(Ysi)\ (Ypi)},$$

$$MP = (Ysi+Ypi) / 2$$

Statistical analysis

Data were subjected to analysis by SAS and MINITAB and graphs were drawn using Excel software.

RESULTS AND DISCUSSION

Vegetative and reproductive growth periods

Based on the results of the variance of analysis (data not shown), it was found that the main effect of vegetative growth period ($P < 0.01$) were significant (Table 1). Mean comparison of the vegetative growth period illustrated that irrigated culture was superior to rain fed. ILL 1324 cv. was placed in the lowest group while, ILL 1180, ILL 1251 and the native cultivars significantly were placed in the highest group (Table 2). Interaction effect of irrigation × cultivar for this trait revealed that ILL 1180 and ILL 1324 cultivars possessed the longest and shortest vegetative growth period. By the way, all the cultivars under the irrigated conditions showed significant difference for the main effect of irrigation, than the rain fed (Figure 1) in which the available water caused increase in the vegetative growth period. Also, ILL 1180 and ILL 1324 cultivars showed the longest and shortest period, under rain fed conditions, respectively. According to Giller (2001), optimum status of the vegetative growth period, has the positive correlation with the biological nitrogen fixation system so that it can be attributed to the favorite activity of the nodules for nitrogen fixation. Drought stress, during the vegetative growth period, leads to the limitation of vegetative growth (Redden and Hemdge, 1999).

Based on the analysis of variance, it was found that only the irrigated conditions showed significant ($P < 0.01$) difference (Table 1). Mean comparisons of the simple effect of the length of reproductive growth period illustrated that irrigation was superior to rain fed. For the simple effect of cultivar, it was cleared that despite the insignificant value of this factor, ILL 1324 and ILL 1180 cultivars possessed the lowest and highest reproductive growth period, respectively (Table 2). The findings of Redden and Hemdge (1999) are in accordance with our findings.

Total number of pods and seeds per plant

Based on the analysis of variance (Table 1), total number of pods per plant was significantly affected by irrigation ($P < 0.01$) and cultivar ($P < 0.05$). Mean comparisons of the simple effect under irrigation conditions, revealed that total number of pods per plant was higher than that of rain fed. For the simple effect of cultivar, ILL 1324 and ILL 1237 cultivars jointly were placed in the lowest group while, ILL 1180 significantly gained the highest total number of pods per plant (Table 2). ILL 1324 and ILL 1237 significantly were the same, possessing the lowest yield and 100-seed weight. On the contrary, ILL 1180 and ILL 1251 cultivars gained the highest yield due to the highest number of seeds per plant, pods per plant and 100-seed weight (Table 2). Niari (2003) reported that Ziba cultivar had more pods per plant than others. Also, Khan and Stoffela (1985) illustrated that there was high positive correlation among the yield and number of pods per plant. Stotzel and Aufhammer (1992) showed that the yield per unit area is a function of pod number per plant. Azizi et al. (2009) found that number of pods per plant is the most important yield component in lentil and number of seed per plant and 100-seed weight, are of lower importance, respectively. Askari et al. (2009) reported that irrigation had significant impact on the pod number per plant in lentil.

According to the analysis (Table 1), total number of seeds per plant, significantly ($P < 0.01$) was affected by irrigation and cultivar ($P < 0.05$). Mean comparisons of the simple effect, for irrigation conditions, showed that irrigation significantly increased total number of pods per plant. For the cultivar, it was illustrated that ILL 1324 and ILL 1237 cultivars were placed at the lowest group while, ILL 1180 gained the highest rate (Table 2). It was cleared that however, ILL 1324 was placed in the same group with ILL 1237, but gained the lowest 100-seed weight, yield and total number of pods per plant. In contrast, ILL 1180 and ILL 1251 cultivars gained the highest 100-seed weight, seed number per plant, the longest period of vegetative and reproductive growth and total number of pods per plant (Table 2). Rafezi et al. (1999) compared 23 native lines of Ardabil, Iran, and two others named Syrian and Ziba, and found that the latter was superior in terms of seed yield and seed number per plant. In another experiment performed under irrigated conditions, it was found that soybean seed number per plant had the highest positive and significant correlation with the seed yield (Khajavinejad et al., 2000). Also, Goldani and Bagheri (1998) found that chickpea karaj cultivar gained the highest seed number per plant under irrigated conditions.

100-seed weight, yield and harvest index

Based on the results of the analysis of variance (Table 1), 100-seed weight only was significant for the cultivar ($P < 0.01$) and no significant difference was observed for the irrigation and cultivar × irrigation interaction. According to the mean comparisons (Table 2), it was found that despite the insignificance of irrigated conditions for this feature; 100-seed weight was higher than rain fed. Considering the cultivar effect, ILL 1180 showed the highest 100-seed weight; it was placed in the same group with ILL 1251 and ILL 1237 cultivars and ILL 1324 showed the lowest 100-seed weight. Hansen and Burton (1994) showed that 1000-seed weight had no impact on the yield of soybean. Also, Kanooni et al. (2008) found that there is positive and insignificant correlation between yield and 100-seed weight of the soybean under rain fed conditions. Raei et al. (2009) observed that irrigation was significant on the 100-seed weight of chickpea.

Table 1. Analysis variance of measured traits.

Sources of variation	Df	MS						
		Vegetative growth period	Reproductive growth period	Total number of pods per plant	Total number of seeds per plant	100-seed weight	Grain yield	Harvest index
Replication	2	0.23ns	5.03ns	5.49ns	0.46ns	0.50ns	16905.05ns	0.00ns
Condition (C)	1	616.53**	56.03**	246.53**	612.91**	0.009ns	1163702.7**	30.00ns
Varieties (V)	4	5.21*	1.58ns	63.77*	95.88*	1.87**	25747.81ns	*14.86ns*
C × V	4	3.11*	2.78ns	21.09ns	9.62ns	0.33ns	4529.15ns	6.83ns
Error	18	1.19	2.70	26.88	42.99	0.38	20099.06	11.77
CV%	-	2.31	4.46	25.73	26.87	16.60	13.08	8.84

*, ** and ns, significant in 1 and 5% and non significant, respectively.

Table 2. Main comparison of simple effects of measured traits.

Trait		Vegetative growth period (DAP*)	Reproductive growth periods (DAP)	Total number of pods per plant	Total number of seeds per plant	100-seed weight (g)	Grain yield (kg ha^{-1})	Harvest index (%)
Conditions of planting	irrigation	51.80a	38.20a	23.01a	28.92a	3.53a	1280.13a	39.80a
	non-irrigation	42.73b	35.46b	17.28b	19.88b	3.49a	886.23b	37.80a
Cultivars	ILL1180	48.33a	37.50a	24.76a	30.40a	3.94a	1167.64a	41.16a
	ILL1324	45.83b	36.16a	16.73b	21.30b	2.60b	1012.72a	36.83a
	ILL1251	47.66a	37.00a	22.03ab	26.60ab	3.93a	1134.63a	39.00a
	Native	47.50a	37.00a	19.36ab	22.33ab	3.71a	1062.20a	38.83a
	ILL1237	47.00ab	36.50a	17.83b	21.36b	3.37a	1038.70a	38.16a

*Numbers with the same letter in each column, have no significant differences to each other; *DAP, day after planting.

As shown in Table 1, seed yield only showed significant difference for the irrigation ($P < 0.01$), and in Table 2, irrigation led to the high seed yield than rain fed. Regarding the cultivars, there was no significant difference across them; however, ILL 1180 and ILL 1324 had the highest and lowest seed yield. Najafi et al. (2008) found that white bean and soya bean gained the highest and lowest yield of 1894 and 308 kg ha^{-1} under irrigated conditions, respectively.

As shown in Table 1, harvest index was insignificant for neither simple, nor interaction effects of irrigation × cultivar, however, it was found that harvest index rate was higher under irrigation conditions than in the rain fed. Like the other traits, the highest and lowest rate of the harvest index belonged to the ILL 1180 and ILL 1324, respectively. Insignificance of this trait seems to be due to proportional increase in the biologic yield along with the seed yield. In an experiment, it was observed that direct impact of the harvest index and biologic yield was less significant on the seed yield (Azizi et al., 209). Nakhforosh and Koochaki (1999) reported that the harvest index may be used as a basis for the yield selection in lentil since, correlation between the seed yield and harvest index was positive and significant. Rafezi et al. (1999) showed that the harvest index had significant correlation with the seed weight and seed number per plant. Also, Ponnu and

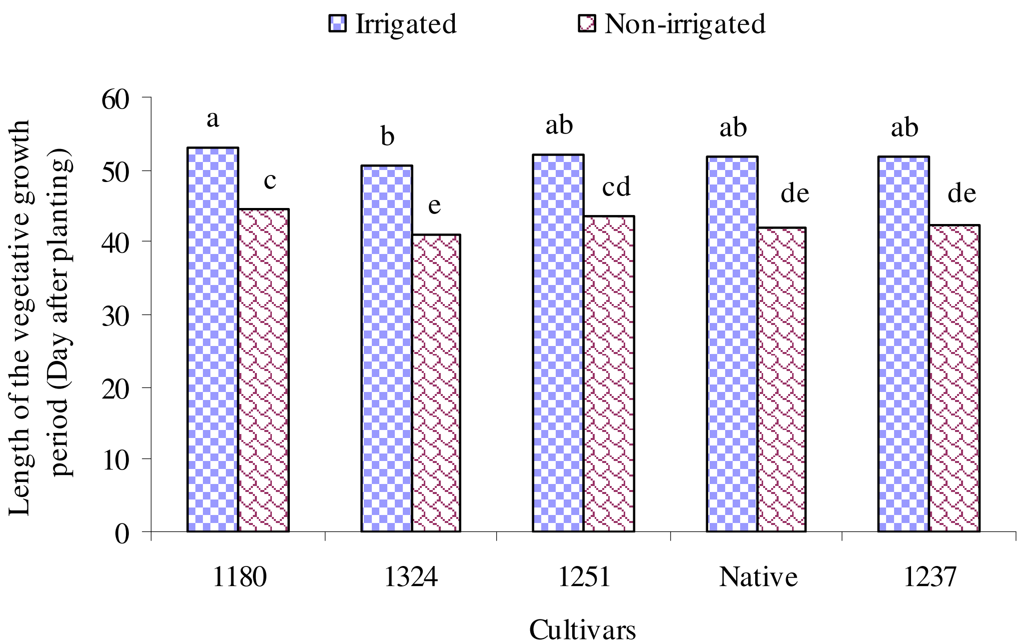


Figure 1. Length of the vegetative growth period as affected by combination of cultivars and irrigated conditions.

Table 3. Indices of drought tolerance cultivars studied.

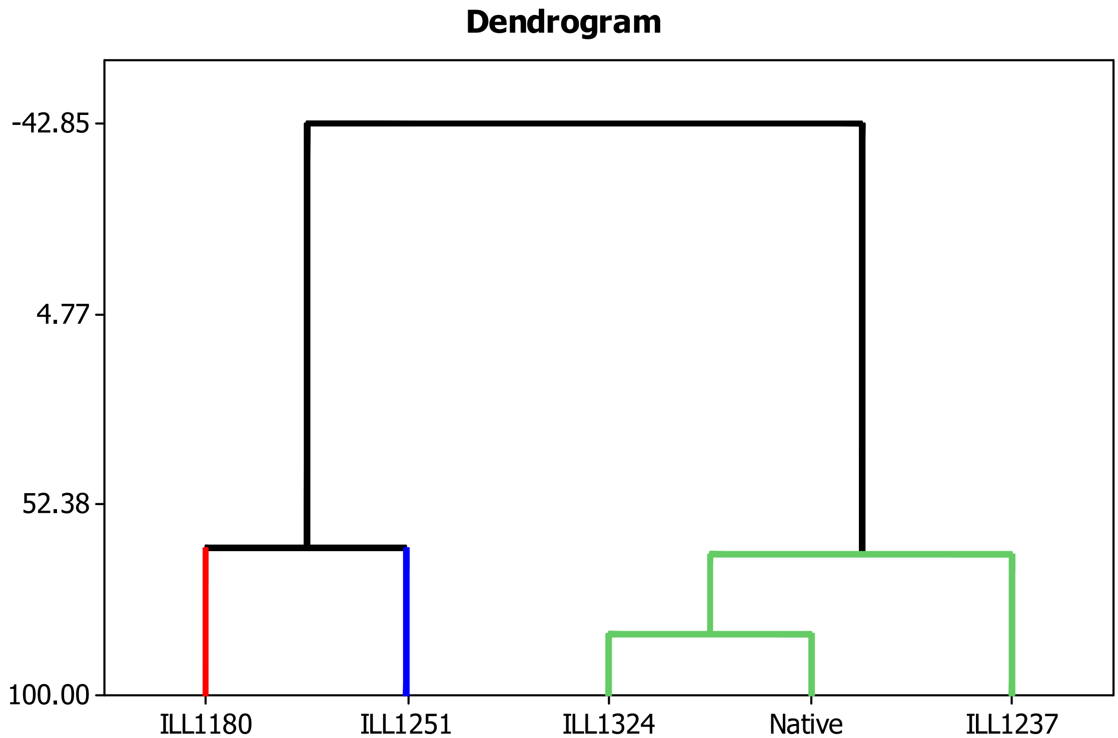
Cultivar	Ypi	Ysi	SSI	TOL	STI	GMP	MP
ILL1180	1321.753	1013.533	0.7578	308.22	0.8174	1157.428	1167.643
ILL1324	1262.966	814.433	1.1541	448.533	0.6276	1014.200	1038.7
ILL1251	1329.000	940.266	0.9505	388.733	0.7625	1117.861	1134.633
Native	1279.766	844.633	1.1049	435.133	0.6596	1039.679	1062.2
ILL1237	1207.166	818.266	1.0469	388.9	0.6027	993.873	1012.716

Singh (1993) reported that the harvest index was increased as a result of irrigation.

Drought resistance indices

Yield rates under stress (Ysi) and optimum (Ypi) conditions, and other drought resistance indices are shown in Table 3. According to the dendrogram derived from the cluster analysis based on the rain fed conditions (Figure 2), it was illustrated that ILL 1180 and ILL 1251 cultivars were of high yields in the same group and the rest were placed in the second group whereas, the above-mentioned cultivars gained the highest yields in both conditions. As with the tolerance index (TOL), higher values indicate susceptibility of the given cultivar and so, selection was performed based on the lower rates of this index. According to this, ILL 1180 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 solely on the basis of having high yields in normal conditions from those having optimum yields under stress is available using MP and TOL indices (Rosielle and Hamblin, 1981). It was found that ILL 1180 and ILL 1237 cultivars showed the highest and lowest GMP.

The lowest rate of the stress susceptibility index (SSI) indicated lower differences in the yield across the stress and normal conditions and hence, more 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 1180 and ILL 1215 had the lowest rate and in contrast, ILL 1324 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



Figjure 2. Dendrogram of the lentil cultivars based on the yield, under irrigation and non-irrigation conditions.

Table 4. Analysis of the main components

Index	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Y_{Pi}	0.339	0.605	-0.046	-0.358	0.337	-0.398	-0.341
Y_S	0.400	-0.055	-0.285	-0.226	0.475	0.597	0.348
SSI	-0375	0.402	-0.627	0.248	0.038	-0.207	0.446
TOL	-0.333	0.632	0.412	0.037	-0.066	0.560	-0.025
STI	0.399	0.120	-0.222	0.754	-0.036	0.192	-0.413
GMP	0.398	0.138	0.511	0.327	0.052	-0.283	0.610
MP	0.395	0.191	-0.208	-0.286	-0.807	0.103	0.144
Variance (%)	88.9	11.01	0.00	0.00	0.00	0.00	0.00
Calamities variance (%)	88.9	99.9	1	1	1	1	1

criterion for assessment of the plant drought resistance. It was seen that ILL 1180 and ILL 1251 had the highest rates, and ILL 1237 and ILL 1324 had the lowest values of STI. Fernandez (1992) suggested that the more sustainable cultivars have the highest range of this index. Thus, distinguishing the high yielding cultivars under both stress and normal conditions is possible.

Considering that 99.9% of the changes can be interpreted by the first two components and the removal of other components did not affect the changes, drawing biplot based on the two components was performed. For the first component, 88.9% of the changes was justified and for the second component 11.01% of the change was justified (Table 4). According to the two separate groups of components within the cultivars based on the amount of performance and stress tolerance, biplot graphs were plotted (Figure 3). Based on the first two components the biplot diagram was divided into four parts. The cultivars were in the area A, in both conditions, they were highest yield. The cultivars were in the D had the lowest yield in both conditions. Thus, the native varieties, the most tolerant cultivars and varieties ILL1251 as the most sensitive, areas A and D were compared. Indices that highly correlated with yield under stress and had normal function and the angle between the normal and stress conditions were also superior as indicators

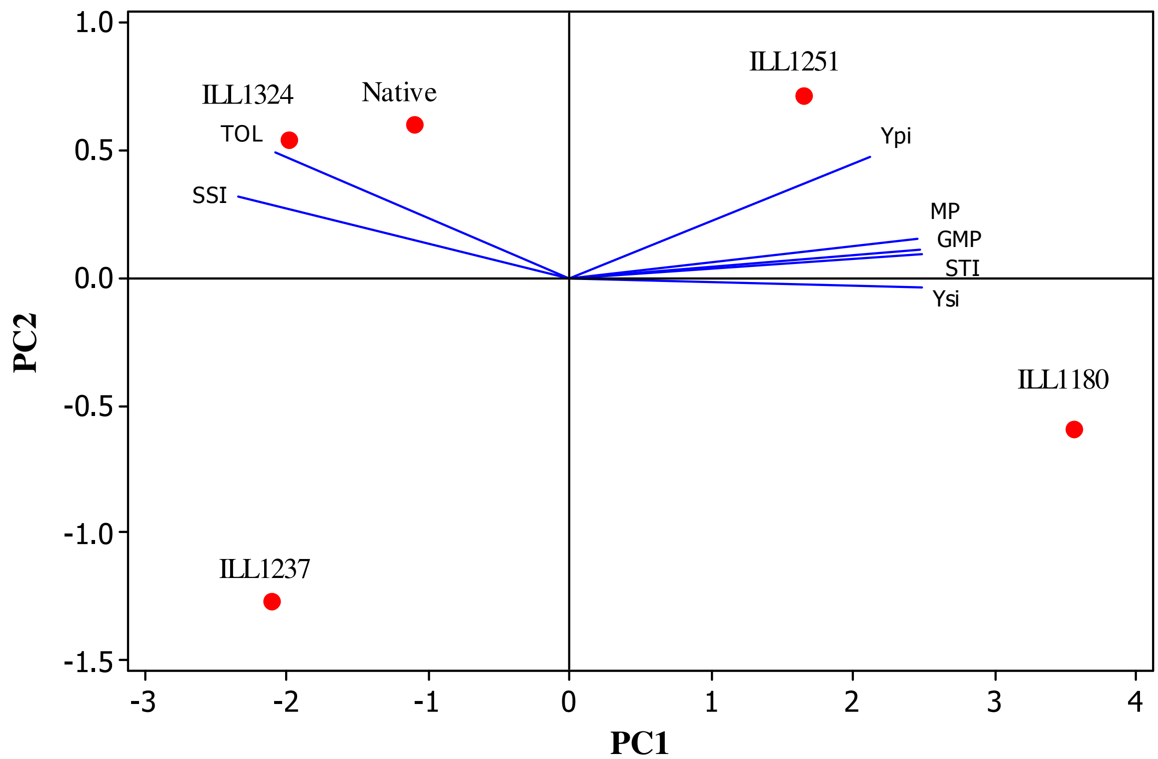


Figure 3. Biplot of the lentil cultivars for drought resistance indices, under irrigation and non-irrigation conditions.

were introduced. These indicators included GMP, MP, and had STI. The results of Moghaddam and Hadizadeh (2002), which fully confor-med to their MP, announced the selection index cultivars tolerant to stress better than SSI and TOL indices.

Conclusions

Totally, it was found that all the measured traits under the irrigated conditions were of higher values than the rain fed. Also, it was clear that ILL 1180 and ILL 1324 culti-vars had the highest and lowest rates for all the measured traits, respectively. It was found that the yield loss of the following cultivars under rain fed conditions included: 308.22 kg ha^{-1} (23.31%) for ILL1180, 448.53 kg ha^{-1} (35.51%) for ILL 1324, for 388.74 kg ha^{-1} (29.25%) ILL 1251, 435.13 kg ha^{-1} (34.00%) for native cultivar and of 388.90 kg ha^{-1} (32.21%) ILL 1237). Also, ILL 1180 had the lowest TOL and SSI and the highest MP, GMP and STI. The highest rates of TOL, SSI and STI belonged to ILL 1324 and ILL 1237 which involved the lowest MP and GMP. Since, the highest yield under stress and normal conditions belonged to ILL 1180 and it included the lowest yield loss under stress and also having the highest drought resistance as with the various indices, it can be considered as the superior cv. and ILL 1237, as the most susceptible one.

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REFERENCES

Amin MN, Hossain A, Roy K (2004). Effect of moisture content on some physical properties of lentil seeds. J. Food Eng. 65: 83-87.
Askari N, Aeeneband A, Poursiabidi M (2009). Influence of complementary irrigation on the yield and yield components of three lentil cultivars in Ilam. Iran. The 10th Iranian congress crop sciences, p. 368.
Azizi CSH, Mostafaei H, Hassanpanah D, Kazemi Arbat H, Yarnia M, Dadashi M, Safaripour F (2009). Path analysis of the yield and yield components of advanced cultivars of lentil under rain fed conditions. The 10th Iranian congress crop sciences. p. 156.
Clarke JM, DePauw RM, Townley-Smith TF (1992). Evaluation of methods for quantification of drought tolerance in wheat. Crop Sci. 32: 423-428.
Desclaus D, Huynh TT, Roumet P (2000). Identification of soybean plant characteristics that indicate the timing of drought stress. Crop Sci. 40: 716-722.
Eskine W, Ashkar FE (1993). Rain fall and temperature effects on lentil (lens culinais Medik) Seed Yield in Mediterranean environments J. Agric. Sci. Cam. 126: 335-341.

Ferguson ME, Robertson LD, Ford-Lloyed V, Newbury HJ, Maxted N (1998). Contrasting genetic variation amongst lentil landraces from different geographical origins. Euphytoca, 102: 26-273.

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. Agric. Res. 29: 897-912.

Foroud N, Mundel HH, Saindon G, Entz T (1993). Effect of level and timing of moisture stress on soybean yield, protein and oil responses Field. Crops Res. 31: 195-209.

Fredrick JR, Camp CR, Bauer PH (2001). Drought-stress effects on branch and mainstem seed yield and yield components of determinate soybean. Crop Sci. 41: 759-763.

Giller KE (2001). Nitrogen Fixation in Cropping Systems. 2nd Edition. CAB, Publishing.

Goldani M, Bagheri A (1998). Possibility evaluation of autumn or winter cropping of chickpea in Mashad, Iran. The 5th Iranian Congress Crop Sciences, p. 404.

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.

Hansen WD, Burton JW (1994). Control for rate of seed development and seed yield potential in soybean. Crop Sci. 34: 131-134.

Hudak CM, Patterson RP (1995). Vegetative growth analysis of a drought–resistant soybean plant introduction. Crop Sci. 35: 464-471.

Kahn BA, Stoffela PJ (1985). Yield Component of cowpea grown in to environment. Crop Sci. 25: 79-182.

Kanooni H, Talei A, Khalili M (2008). Yield and 100-seed weight sustainability analysis of chickpea genotypes under rain fed conditions. Seed Plant J. 23(3): 297-310.

Katerji N, Vanhoorn JW, Hamdy A, Mastrorilli M (2000). Salt tolerance classification of crops to soil salinity and to water stress day index. Agric. Water Manage. 43: 99-109.

Khajavinejad GH, Kazemi H, Alyari H, Javanshir A, Arvin M (2000). Effects of different irrigation regimes and plant densities on the growth features, yield and yield components of soybean. J. Agro. Sci. 14(2): 57-70.

Koochaki A, Sarmadnia GH (2002). Crop plants physiology (translated). Jahad Daneshgahi Mashad Press. p. 400.

Kusmenglu I, Muehlbauer FJ (1998). Genetic variation for biomass and residue production Lentil: II. Factors determining seed and straw yield. Crop Sci. 38: 911-917.

Lessani H, Mojtahedi M (2003). Basis of the plant physiology. Tehran University Press. p. 726.

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. Iran. J. Seed. Seedling, 18: 255-272.

Najafi H, Ganjali A, Parsa H, Rafei A (2008). Study of phenologic and morphologic traits and the yield and yield components of different common bean in Neishaboor, Iran. J. Agro. Sci. 10: 229-324.

Nakhforosh A, Koochaki A (1999). Effects of the morphologic and physiologic aspects on the yield and yield components of lentil genotypes. The 5th congress of Iranian Crop Sciences, p. 234.

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.

Niari KN (2003). Response of the physiologic and agronomic traits of lentil to different soil humidity regimes. MSc thesis, faculty of agriculture, Tabriz University.

Ponnu RK, Singh DP (1993). Effect of irrigation and water use, water-use efficiency, growth and yield in mungbean. Field Crop Res. 31: 87-100.

Raei Y, Demaghsi N, Seyedsharifi R (2009). Evaluation of water deficit and plant population on the yield and yield components of chickpea, kaka ultivar. The 5th Iranian Congress Crop Sciences, p. 476.

Rafezi R, Moghadam Vahed M, Valizadeh M (1999). Investigation of genetic diversity and correlations between yield and yield components using path analysis in lentil. The 5th Iranian Congress Crop Sciences, pp. 29-30.

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

Redden RJ, Hemdge DF (1999). Evaluation of genotypes of navy and culinary bean (*Phaseolus vulgaris* L.) selected for superior growth and nitrogen fixation. Aus. J. Exp. Agric. 39: 975-980.

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

Schmidtke K, Neumann A, Hof G (2004). Soil and atmospheric nitrogen uptake by lentil and barly as monocarps and intercrops. Field Crops Res. 87: 245-256.

Sinha SK, Bhargava SC, Baldev B (1988). Physiological Aspects of pulse crops. In Baldev B, Ramanujam S, Jain HK (eds.), plus Crops. Oxford and IBH. pp. 421-455.

Stotzel H, Aufhammer W (1992). Grain yield in determinate and indeterminate Clutivar of vicia faba with different Plant distribution Patterns and Population densities. J. Agric. Sci. Cam. 118: 343-352.