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PHENOTYPIC ADAPTABILITY AND STABILITY OF MACROSPERMA LENTIL LANDRACES IN DARA'A GOVRENORATE, SYRIA

SUMMARY

The objective of this work was to evaluate the adaptability and stability of ten macrosperma lentil (Lens culinaris Medik.) landraces under a wide range of variable environments. The regression model was used to analyze the response of lentil landraces to variable environmental conditions for grain yield and some of its components in three seasons (2010/2011, 2011/2012 and 2012/2013) under one location at Dara'a Governorate, Syria. The experimental design was the randomized complete blocks with three replicates. Results indicated that both environmental conditions (E) and studied genotypic accessions (G) influenced significantly on grain yield. Moreover, the performance of genotypes (landraces) varied significantly from environment to another for all the traits under study as proved by significance of G×E. For 100-grain weight, two landraces 55515 and 55517 were stable and recorded higher mean value than the grand mean. For grain yield, just one landrace 55516 was stable and high mean performance and may be recommended under favorable or rich environments.

Keywords: lentil, landraces, regression model, adaptability

INTRODUCTION

Lentil (Lens culinaris Medik.) is an important cool-season crop and a valuable source of dietary protein for human consumption and animal feed (Sabaghnia *et al*., 2012). Sowing legumes in a rotation with cereals has been shown to be beneficial in many semi-arid areas of the Middle East. In most lentil production areas yields seem to be no more than one-half of potential yields while improved genotypes contribute to increase lentil production and yields (Erskine, 2009).

Genotype×environment interaction refers to as differential response of genotypes or cultivars to across a range of environments. Specific adaptation of genotypes to subset of environments is a fundamental issue to be studied in plant breeding programs; because one genotype may perform well under specific environmental conditions and may give a poor performance under other conditions (Yan *et al*., 2001). It has been observed that the magnitude of the G×E interactions is a linear function of the environmental effects. Thus, differences in response by individual genotypes to a wide range of environments often, follow

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an orderly pattern which can be measured as differences between coefficients of linear regression of individual genotypes in the environments (Hill, 1975).

Genotype×environment interaction is an important issue in the improvement of breeding materials; because it reduces grain yield stability in different environments (Loffler *et al*., 2005). In most multi-environmental trials, G×E interaction impedes plant breeding progress for broad as well as specific adaptation (Dreccer *et al*., 2008). The effectiveness of evaluating new improved genotypes is affected by understanding of G×E interaction and the degree to which the test locations are presented in multi-environmental trials (Poldich and Cooper, 1998).

A variety is considered more adaptive or stable if it has a high mean of yield with low degree of fluctuation in yield ability when grown over different locations or seasons (Amin *et al*., 2005). Lentil genotypes suffer from narrow adaptability; due to long-day sensitivity performance and susceptibility to less favorable environments (Erskine and Saxena, 1993). Thus, the most important goal of lentil improvement programs not only high yield, biotic and abiotic stress tolerant cultivars, but also wide adaptability and stability (Dehghani *et al*., 2008).

The present study was carried out to achieve the following goals:

-Determining the magnitude of G×E interaction variation in ten macrosperma lentil landraces regarding grain yield and some of its components.

-Determining adaptability and stability parameters of these landraces under different environments (seasons) at Dara'a Governorate, Syria.

MATERIAL AND METHODS

Ten macrosperma lentil landraces namely 55505, 55509, 55511, 55512, 55515, 55516, 55517, 55519, 55520 and 55526 obtained from Department of Genetic Resources, General Commission for Scientific Agricultural Research (GCSAR), Syria, were evaluated under three environments presented three successive growing seasons (2010/2011, 2011/2012 and 2012/2013) at Dara'a Center of Scientific Agricultural Research, GCSAR, Syria. A randomized complete blocks design (RCBD), with three replicates was used. The experimental unit consisted of 4 rows 0.3 m apart and 4 m long under rainfed conditions. All the agricultural practices used for lentil production were carried out in all the experiments in accordance with locally recommended practices. Ten plant samples per plot were randomly used for measuring the yield components viz., number of primary branches/plant, number of pods/plant and 100-grain weight (g). While data for grain yield/plot were recorded at the end of harvest season and converted to kg/dunam (Dunam = 0.1 hectare).

Analysis of variance at 0.05 and 0.01 level of significance for the data from each individual environment (season) were analyzed, using proc. ANOVA (SAS Institute, 2002) for the studied traits, according to Steel and Torrie (1980). Data were subjected to combined statistical analysis across environments using proc. IML and proc. Mixed (Littell *et al*., 1996). Stability analysis for the investigated traits was performed according to the model of Eberhart and Russell

(1966). From the regression analysis, the following three estimates of stability parameters were calculated; linear regression coefficient (b_i) and mean square of deviation from regression line (S^2d_i) as well as determination coefficient (R^2) as explained by Petersen (1989) for each genotype (landrace). The three estimates of stability parameters in addition to the mean of the studied traits were included to determine the most stable genotype.

RESULTS AND DISCUSSION

Mean performance of lentil landraces over the different environments

Analysis of variance presented in Table 1 showed that just grain yield had significant genotypic differences indicating that the evaluated landraces differed in their genetic potentials concerning this trait. Yield and its components reflected clear and highly significant effect for the environmental factors (seasons); suggesting that there were some obvious fluctuations in the environmental conditions throughout the different experiments of the present study.

G×E interactions appeared to be significant for number of primary branches/plant and highly significant for the other traits (Table 1); indicating that the genotypes (landraces) tended to rank differently when grown at different seasons as well as the evaluated landraces showed different response when grown under variable environments and should be measured over multiple seasons to separate G×E interaction component from the total genotypic variance. The relative importance of year as a factor affecting G×E interaction has been repeatedly reported suggesting the need for testing in more years, rather than more locations (Brandle and McVetty, 1988; Biarnes-Dumoulin *et al*., 1996). Evaluation of genotypes over several years appears to improve genotype evaluation and it would enable characterization of each genotype for intra-location variance to evaluate the non-predictable part of the G×E interactions, due to annual effects (Lin and Binns, 1988).

Furthermore, the higher magnitude of mean squares due to environments (linear) as compared to G×E (linear) showed that linear response of environments accounted for the major part of total variation for all the studied traits. Although smaller in magnitude compared to the linear component, the highly significant pooled deviation from the regression for grain yield and its components, demonstrated the presence of a degree of non-linearity in the G×E interactions. Similar environmental effects on the performance of lentil genotypes and the G×E interactions were previously detected by Hamdi *et al*. (2002); Karimizadeh *et al*. (2011).

The individual performance of the lentil landraces over the three seasons for grain yield and its components along with the grand mean and environmental indices are presented in Table 2. Number of pods/plant and grain yield had the highest values of environmental index (Ij), while the lowest values were recorded by number of primary branches/plant and 100-grain weight.

Table 1. Analysis of variance for stability over the three environments (seasons) for grain yield and some of its components in 10 macrosperma lentil landraces

Source	d.f.	Mean sum of squares for the studied traits: No. of primary branches/plant	No. of pods/plant	100-Grain weight	Grain yield
Genotypes (G)	9	1.74	135.44	0.63	219.39*
Environments (E)	2	2.07**	2352**	4.84**	2678.27**
G×E	18	0.44*	83.93**	0.51**	84.78**
E + (G×E)	20	0.94	300.97**	0.95*	344.11**
E (linear)	1	4.13	4704.16**	9.72**	5352.66**
G×E (linear)	9	0.32	79.97	0.66	90.21
Pooled deviation	10	1.17**	59.55**	0.33**	71.78**
55505	1	0.19	189.30**	0.33*	23.90**
55509	1	2.55**	17.70	0.25	9.01
55511	1	0.44	4.23	1.14**	37.42**
55512	1	0.00	8.10	0.94**	308.04**
55515	1	0.61	15.31	0.01	31.14**
55516	1	0.10	43.30	0.44*	1.17
55517	1	0.02	150.40**	0.10	22.88**
55519	1	1.98**	30.84	0.01	127.73**
55520	1	5.80**	133.38**	0.04	19.20**
55526	1	0.01	2.92	0.01	137.27**
Pooled error	60	0.20	15.32	0.07	2.48

*, ** - significant at 0.05 and 0.01 probability level, respectively.

It could be concluded that both seasons 2011/2012 and 2012/2013 represented favourable environments for all the traits under study compared to the first season 2010/2011 as indicated by the positive values of environmental indices. Abo-Hegazy *et al*. (2013) found that the highest estimates of environmental index were recorded for pods/plant and seed yield, but the lowest ones had seeds/pod and 100-seed weight.

In Syria, the latter part of the reproductive growth phase in lentil often coincides with increasing temperatures and dry conditions and this exaggerates the indeterminate nature of the crop, leading to immature pod/grain development, and subsequently resulting inforced maturity with low grain yield. Since lentil is primarily a rainfed crop, yield stability is a major objective in any breeding program. This could be achieved through a better understanding of the components contributing to final yield. However, these components vary from year to year and from location to another, even for the same lentil genotype (Tullu *et al*., 2001).

Table 2. Mean performance of 10 macrosperma lentil landraces for the studied traits over the three study seasons

Landraces	No. of primary branches/plant				No. of pods/plant			
	2010/2011	2011/2012	2012/2013	Mean	2010/2011	2011/2012	2012/2013	Mean
55505	3.00	3.00	3.67	3.22	26.33	27.33	45.67	33.11
55509	2.67	2.00	4.33	3.00	32.00	55.33	58.33	48.55
55511	3.67	3.67	4.67	4.00	19.00	44.67	45.00	36.22
55512	3.67	3.67	3.67	3.67	36.00	62.00	55.33	51.11
55515	2.33	3.33	4.67	3.44	22.67	38.67	42.33	34.56
55516	2.00	3.33	4.00	3.11	25.00	42.67	49.33	39.00
55517	3.00	4.00	4.33	3.78	30.67	68.33	47.67	48.89
55519	4.33	5.33	3.33	4.33	30.00	67.67	55.67	51.11
55520	4.33	6.67	3.33	4.78	19.00	76.33	54.00	49.78
55526	3.33	4.67	4.67	4.22	18.33	56.33	53.67	42.78
Env. index	-0.52	0.21	0.31	-	-17.61	10.42	7.19	-
Grand Mean	3.76				43.51			

Landraces	100-Grain weight (g)				Grain yield (kg/d)			
	2010/2011	2011/2012	2012/2013	Mean	2010/2011	2011/2012	2012/2013	Mean
55505	3.03	4.83	4.23	4.03	20.33	25.67	40.13	28.71
55509	2.00	3.33	2.77	2.70	12.67	22.40	35.60	23.56
55511	4.47	2.99	4.40	3.95	16.67	23.90	42.23	27.60
55512	2.97	2.77	4.23	3.32	16.67	51.63	40.07	36.12
55515	2.00	4.38	4.77	3.72	17.33	24.20	41.17	27.57
55516	2.20	4.99	4.43	3.87	13.67	38.20	53.57	35.15
55517	2.77	4.33	4.17	3.76	11.67	36.97	45.70	31.45
55519	2.57	3.28	3.20	3.02	24.00	27.40	54.27	35.22
55520	1.93	3.70	4.27	3.30	21.67	41.77	66.47	43.30
55526	2.80	3.20	3.10	3.03	15.33	64.93	76.93	52.40
Env. index	-0.80	0.31	0.49	-	-17.11	1.60	15.50	-
Grand Mean	3.47				34.11			

Stability parameters

Once genotype×environment interactions were significant, stability analysis was performed and values using three different stability parameters were estimated. Estimates of stability parameters (bi, S2di and R2) as well as mean values of grain yield and its components of macrosperma lentil landraces are shown in Table-3. Eberhart and Russell (1966) emphasized that both linear (bi) and non-linear (∂ij) components of G×E interaction should be considered in judging the phenotypic stability of a particular genotype and their responses are independent from each other. Therefore, a variety considered as stable and widely adapted should meet the criteria of high mean performance, with bi non-significantly different from unity and S2di approaching zero (Crossa, 1990).

Number of primary branches/plant

Coefficient regression ranged from (-0.24) for 55519 to (2.29) for 55515. Three landraces 55511, 55517 and 55526 deviated non-significantly from zero (S2di=0). Hence, they were stable and average responsive due to they had regression coefficient values non-different from unit (bi=1.0) as well as they recorded higher mean values (4.00, 3.78 and 4.22), respectively than the grand mean (3.76). However, only the two landraces 55517 and 55526 recorded high values of determination coefficients (0.99, 0.99). Hence, they were suited to all the environments. Lin *et al*. (1986) indicated that the (bi) value is an indicator of the response of variety for predictable or macro-environmental features, while the (S2di) value is an indicator for micro changes.

Number of pods/plant

Five out of ten landraces showed higher mean performance compared with the grand mean (43.51). Three landraces 55505, 55517 and 55520 were unstable; because they exhibited highly significant values of deviation from regression line. Three landraces 55509, 55512 and 55519 recorded higher mean performance (48.55, 51.11, 51.11), respectively, than the grand mean (43.51) along with regression coefficients nearer to unity and non-significant values of deviation from regression; indicating their stability and wide adaptability across all the environments. The coefficients of determination (R2) for these three landraces were as high as (0.96, 0.98, 0.96), respectively, confirming their stability. Abo-Hegazy *et al*. (2013) mentioned that mean performance and bi values for pods/plant ranged from (38.8, 0.47) for ILL4403 to (83.2, 1.41) for Giza 9, respectively.

100-Grain weight

100-Grain weight varied from (2.70 g) for 55509 to (4.03 g) for 55505. Five landraces out of ten had higher mean performance compared to the grand mean (3.47 g), hence, they showed preferable performance. Coefficients of regression (bi) ranged from (-0.50) 55511 to (2.14) 55515. According to Eberhart & Russell (1966), the large variation in values of bi indicates large differences in the genotype response to the different environments. Only one landrace 55517 had desirable performance (3.76 g) along with non-significant estimates of both S2di and bi, hence it was stable and suitable to a wide array of environments as well as it had a high value of R2 (0.93).

Table 3. Mean performance and stability parameters, based on the regression technique for 10 macrosperma lentil landraces grown across the three environments (seasons).

Landraces	No. of primary branches/plant				No. of pods/plant			
	X_i	b_i	S^2d_i	R^2	X_i	b_i	S^2d_i	R^2
55505	3.22	0.51	-0.01	0.36	33.11	0.32	173.98**	0.20
55509	3.00	0.90	2.35**	0.12	48.55	0.92	2.38	0.96
55511	4.00	0.75	0.24	0.35	36.22	0.97	-11.09	0.99
55512	3.67	0.00	0.00	0.00	51.11	0.87	-7.22	0.98
55515	3.44	2.29	0.41	0.80	34.56	0.66	-0.01	0.94
55516	3.11	2.19	-0.10	0.98	39.00	0.76	27.98	0.86
55517	3.78	1.51	-0.18	0.99	48.89	1.09	135.08**	0.79
55519	4.33	-0.24	1.78**	0.01	51.11	1.23	15.52	0.96
55520	4.78	0.44	5.60**	0.01	49.78	1.81	118.06**	0.92
55526	4.22	1.70	-0.19	0.99	42.78	1.38*	-12.40	0.99
Grand mean±S.E.	3.76±0.77	1.00±1.69	-	-	43.51±5.46	1.00±0.36	-	-

Landraces	100-Grain weight				Grain yield			
	X_i (g)	b_i	S^2d_i	R^2	X_i (kg/d)	b_i	S^2d_i	R^2
55505	4.03	1.17	0.26*	0.78	28.71	0.59	21.42**	0.89
55509	2.70	0.81	0.18	0.71	23.56	0.69	6.53	0.96
55511	3.95	-0.50	1.07**	0.18	27.60	0.76	34.94**	0.89
55512	3.32	0.56	0.87**	0.25	36.12	0.78	305.56**	0.51
55515	3.72	2.14*	-0.06	0.99	27.57	0.71	28.66**	0.90
55516	3.87	2.00	0.37*	0.90	35.15	1.23*	-1.31	0.99
55517	3.76	1.18	0.03	0.93	31.45	1.06	20.40**	0.96
55519	3.02	0.54	-0.06	0.96	35.22	0.89	125.25**	0.77
55520	3.30	1.73	-0.03	0.98	43.30	1.36	16.72**	0.98
55526	3.03	0.28	-0.06	0.89	52.40	1.93	134.79**	0.94
Grand mean ±S.E.	3.47± 0.41	1.00± 0.58	-	-	34.11± 5.99	1.00± 0.37	-	-

*,** - significant at 0.05 and 0.01 probability level, respectively

The landrace 55515 showed preferable performance (3.72 g), non-significant deviation from regression (S2di=0); so, it was stable along with high value of R2 (0.99). However, this landrace had bi>1* (2.14); suggesting its sensitivity to environmental changes in addition to greater specifity of adaptability to high-yielding or favorable environments. Abo-Hegazy *et al.* (2013) found non-significant G×E interaction for 100-seed weight; so, stability parameters were not calculated.

Grain yield

Mean of grain yield over the three study seasons varied from (23.56 kg/d) 55509 to (52.40 kg/d) 55526. Five landraces viz., 55512, 55516, 55519, 55520 and 55526 exhibited high mean yields compared to the general mean (34.11 kg/d), hence, they were desirable performance. Coefficients of regression ranged from (0.59) 55505 to (1.93) 55526. High positive values of bi indicated that grain yield increased as environmental index increased. While, low estimates of bi suggested that grain yield did not increase as environmental index increased. Two landraces 55509 and 55516 were stable (S2di=0). Unfortunately, nevertheless, the landrace 55509 had stable performance and average responsiveness, it recorded less mean performance (23.56 kg/d) than the grand mean (34.11 kg/d). Therefore, the landrace 55509 cannot be recommended. The landrace 55516 had a desirable performance (35.15 kg/d), a high value of determination coefficient (0.99) confirming its stability and bi>1* ; indicating its sensitivity to environmental changes and, hence, it could be recommended for cultivation in favorable or high technology level environments. Ali *et al.* (2012) reported that the values of mean yield and regression coefficient varied from (778 kg/ha, 0.83) for Masoor-93 to (1140 kg/h, 1.09), respectively, for 12 lentil genotypes evaluated over 11 locations for two cropping seasons. The trend of these findings was in accordance with Dehghani *et al.* (2008); Szilagyi *et al.* (2011) but contradicted Sabaghnia *et al.* (2012); who found non-significant mean squares of genotype×year interaction for seed yield of 10 lentil genotypes examined across 5 locations and 2 growing seasons.

CONCLUSIONS

1.For 100-grain weight, the landrace 55517 had the ability to express its yield potential and it was identified as a good yielding and stable landrace in the range of the tested environments.

2.For grain yield, it was not found any lentil landrace with both stability and broad adaptability for the environments considered in this study.

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FENOTIPSKA PRILAGODLJIVOST I STABILNOST POPULACIJE SJEMENA SOČIVA U GOVERNORATU DARA'A, SIRIJA

SAŽETAK

Cilj ovog rada je procijeniti prilagodljivost i stabilnost populacije od deset sjemena sočiva (Lens culinaris Medik.) u širokom spektru uslova. Za analizu uticaja promjenjljivih uslova sredine na prinos zrna i neke od njegovih komponenti korišten je regresioni model na jednoj lokaciji Governorata Dara'a u Siriji tokom tri sezone (2010/2011, 2011/2012 i 2012/2013). Eksperiment je postavljen po blok sistemu u tri ponavljanja. Rezultati ukazuju da su oba uslova, sredina (E) i ispitivani genotipski aksešeni (G) uticala na prinos zrna. Performanse genotipova (populacija) značajno variraju od sredine do sredine za sve osobine koje su obuhvaćene studijom što dokazuje značaj G×E. Kod mase 100 zrna, dvije populacije i to 55515 i 55517 su bile stabilne i zabilježile su veću srednju vrijednost od prosjeka. Kod prinosa zrna, samo populacija 55516 je bila stabilna i visoke prosječne performanse i može se preporučiti u povoljnim ili bogatim sredinama.

Ključne riječi: sočivo, populacija, regresioni model, prilagodljivost