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IDENTIFYING THE MOST PROMISING GENOTYPES IN LENTIL FOR CULTIVATION IN A WIDE RANGE OF ENVIRONMENTS OF PAKISTAN USING VARIOUS YIELD STABILITY MEASURES

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Abstract

The present study was aimed to identify the most promising high yielding lentil genotype for a wide range of environments of Pakistan using 8 stability measures. The experiment consisted of 12 lentil genotypes grown at 11 locations falling in different agro-ecological zones of Pakistan for 2 years during 2006/07 and 2007/08 under national uniform yield testing. The General Linear Model (GLM) of MINITAB (version 15) was used for two-way analysis of variance for lentil yield data to examine the total variation into genotypes, environments and genotype x environment interaction. The percent variation of 2 major contributors, environment and GxE interaction, was permissible to perform stability analysis to evaluate stable genotypes across the environments. The genotype x environment interaction means were used for eight stability measures (genotype mean, genotype variance, coefficient of variation, ecovalence, interaction variance, regression slope, deviation mean square, coefficient of determination). The stability measures depicted that the genotype NARC-06-1 with high mean yield (1140 kg/ha^{-1}), regression slope (1.09) close to unity and less statistics of remaining stability measures except high value of R^2 for yield proved to be the best within the pool of studied genotypes. The results clearly suggest that the genotype NARC-06-1 may prove to be a widely adapted high yielding stable variety for a broad spectrum of environments of Pakistan.

Introduction

Lentil (*Lens culinaris* Medik.) is an annually sown cool season food legume crop with high protein contents (25-30%) in its grains. It is the second major winter pulse crop after chickpea in Pakistan. It plays an important role in rain-fed (barani) cropping systems, providing an alternative to cereal grains (Hamayun *et al.*, 2011). The total area and production of lentil is decreasing at alarming pace. During the last 10 years (1999/2000 to 2009/2010), the area decreased from 62.5 thousand hectares to 31.6 thousand hectares and production from 35.9 thousand tons to 15.8 thousand tons (GOP, 2010). Consequently, the country imports a large quantity of lentil to meet domestic requirement putting huge burden on the national exchequer. The market price remains relatively high which leads to low per capita consumption. Therefore, the lentil production should be increased at least by three times to bring down the price of this commodity, save the money being spent now on its import and meet the demand of increasing population. So far, only nine varieties have been released in the country. The speeding up of the research work for variety development is urgently needed. The lentil breeding programme at National Agricultural Research Centre (NARC), Islamabad is aimed at the improvement of different plant traits and recombining them into one genetic background to enhance the plant productivity and with an integrated and coordinated approach, increasing the overall production of lentil in the country.

Development of widely adapted genotypes is the goal of almost all breeding programmes. For this purpose, the genotypes are grown in different environments and their yield stability is estimated before giving any recommendations for variety release. The GxE interaction refers to differential responses of genotypes or cultivars across a range of environments (Kang, 1998; Kang, 2004; Shakoor *et al*., 2011). It is a concept well defined in various ways of Genotype x Environment interaction when different genotypes are evaluated across diverse environments (Brancourt-Hulmel & Lecomte, 2003).

A genotype may be considered to be stable if its among environment variance is small, if its response to environments is parallel to the mean response of all genotypes in the trial, and if the residual mean square from a regression on the environmental index is small. Many stability statistics have been used to determine whether or not cultivars evaluated in multi environmental trials are stable (Flores *et al.*, 1998; Robert, 2002; Sabaghnia *et al*., 2006; Rane *et al*., 2007; Akhtar *et al*., 2011). As the most stable genotype(s) may not be the highest yielding, the use of methods that integrate yield performance and stability to select superior genotypes becomes highly important (Kang, 1993). Lin *et al*., (1986) compared nine stability statistics and non-similarity measures and reported three concepts of stability. Rane *et al*., (2007) compared a set of 25 advanced breeding lines of wheat at 18 different environments across the Indo-Gangetic Plains and concluded that emphasis should be given on grain yield stability for breeding for high temperature tolerance which can take care of intralocation variation in genotypic response over the years and dates of sowing. Letta *et al*., (2008) used 5 stability parameters approach to define stable genotypes for 7 quality traits. Sabaghnia *et al.*, (2008) evaluated 11 lentil genotypes across 20 environments in Iran using site regression (SREG) stability model and found that location and genotype x location variabilities were responsible for total yield variation. The ideal genotype was the one which showed both high mean yield and high stability of performance across environments. Based on mean grain yield, regression coefficient and deviation from regression, Anwar *et al*., (2011) and Arain *et al.*, (2011) performed stability analysis for wheat cultivars planted in different sowing times and agro-climatic conditions of Pakistan and found the most stable genotypes for diverse environments. Kayan & Adak (2012) used five statistical procedures to find the most stable genotype in chickpea.

The objective of the present study was to select the best adapted high yielding lentil genotype for a wide range of environments of Pakistan using different yield stability measures.

Materials and Methods

The experiment consisted of 12 lentil genotypes grown at 11 locations in different agro-ecological zones of Pakistan during two cropping seasons of 2006/07 and 2007/08. The trial was laid down in a randomized complete block design (RCBD) with 3 replications having 4-row plot with 30cm row width and 4m row length. Various methods have been proposed for the statistical analysis of interactions in general, and genotype-environment (GE) interactions in particular. To know the presence of interaction and to consider its effect on subsequent work, the data was subjected to analysis of variance (Freeman, 1973). The yield data were subjected to analysis of variance (ANOVA) and combined over for 2 years (Gomes & Gomes, 1984). The General Linear Model (GLM) of MINITAB Version-15 was used to partition yield variation into environments, genotypes and genotypes x environment interaction. The Genotype x Environment interaction means computed for stability measures using Microsoft Excel 2007. The stability measures used to assess the stability and adaptability of genotypes were: within genotype mean square (S_i^2), genotypic coefficient of variation (CV_i %) as used by Francis and Kannenberg (1978), covalence (W_i^2) as proposed by Wricke (1962), interaction variance (σ_i^2) as suggested by Shukla (1972), regression coefficient (b_i) as used by Eberhart & Russell (1966), deviation from regression mean square ($\delta_i 2$) and coefficient of determination (R_i^2) statistics as explained by Petersen (1989).

Results and Discussion

The mean seed yield of the 12 lentil genotypes grown at 11 different locations for 2 cropping seasons is given in Table 1. The genotype NARC-06-1 was found to be the highest yielding with mean seed yield of 1140 kg ha^{-1}. The results of two-way analysis of variance for the yield data gave percent variation as 5.93, 75.27 and 18.80 for genotypes, environments and genotype x environment interaction, respectively. The percent variation of 2 major contributors namely environment and GxE interaction was permissible to perform stability analysis to identify stable genotypes across the environments (Table 2). The stability measures for yield data showed regression coefficients ranged from 0.83 (Masoor-93) to 1.19 (01512). The genotype NARC-06-1 has regression slope close to 1 and high yield mean response with relatively low ecovalence (low contribution to the genotype x environment interaction), lesser values of coefficient of variation, interaction variance, deviation from regression and high value of coefficient of determination (R^2) indicating that this genotype is stable among the genotypes studied at 11 locations (Table 3).

Table 1. Mean seed yield (kg ha^{-1}) of 12 lentil genotypes grown at 11 locations for two cropping seasons during 2006/07 and 2007/08.

Genotype	NARC Isbd.	NIAB F.abad	AARI F.abad	BARI Chak.	BARS F.Jang	AZRI Bhak.	BARS Kohat	ARI DIK	NIA TJ	QAARI Larkana	AZRI DIK	Mean
NL-96625	597	1518	1226	580	598	275	415	668	1589	785	969	838
NARC-06-1	1504	1308	1689	646	695	769	730	972	1476	1609	1144	1140
NARC-06-2	1576	974	1534	678	379	734	473	661	1155	1174	1081	947
NARC-06-3	1452	608	1446	555	411	408	482	680	1111	1288	863	846
NARC-06-4	1525	877	1613	803	493	738	500	622	1216	1091	888	942
NARC-06-5	1702	877	1559	652	384	466	626	740	1007	922	614	868
AEL-23/40	868	1172	1455	684	534	575	659	842	1868	1323	1191	1015
98CL-008	968	1106	1440	704	618	441	476	817	1207	1364	953	917
01505	1274	846	1260	675	458	573	479	678	1521	1313	1247	938
01512	1094	1318	1627	668	566	259	433	685	1433	1067	1161	937
Masoor-93	953	703	1207	623	473	436	428	649	1155	1229	704	778
NIAB Masoor-06	951	816	1498	420	577	360	591	563	1234	996	903	810
Mean	1205	1010	1463	640	515	502	524	714	1331	1180	976	915

Table 2. Two-way analysis of variance for the lentil yield data.

Source of Variation	DF	SSQ	MSQ	Variation Percent
Genotypes (G)	11	1169443	106313	5.93
Environments (E)	10	1485667	1485667	75.27
G x E interaction	110	3710846	33735	18.80
Total sum of squares	131	19736956	150663.8	100.00

Table 3. Yield stability measures for 12 lentil genotypes grown at 11 different locations for two cropping seasons during 2006/07 and 2007/08.

Genotype	Stability Measures*							
	$\acute{Y}_i$	s_i^2	CV_i	W_i^2	σ_i^2	b_i	δ_i^2	R^2
NL-96625	838	190368	52.08	917945	106781	0.90	100223	0.53
NARC-06-1	1140	157186	34.78	115480	10485	1.09	11261	0.94
NARC-06-2	947	160024	42.24	253561	27055	1.05	27448	0.85
NARC-06-3	846	167658	48.43	273665	29467	1.07	29316	0.84
NARC-06-4	942	145364	40.47	254407	27156	0.99	27823	0.83
NARC-06-5	868	177685	48.57	582048	66473	0.99	64221	0.67
AEL-23/40	1015	178337	41.59	424964	47623	1.05	46428	0.77
98CL-008	917	116438	37.20	146740	14236	0.91	14862	0.89
01505	938	151272	41.45	206446	21401	1.03	22387	0.87
01512	937	194498	47.06	257463	27523	1.19	23485	0.89
Masoor-93	778	94463	39.51	145691	14110	0.83	11573	0.89
NIAB Masoor-06	810	123462	43.40	131409	12397	0.95	13814	0.90

*Stability Measures

$\acute{Y}_{i\cdot} = \sum_j y_{ij} / q$ = Genotype Mean

$s_i^2 = \sum_j (y_{ij} - \bar{y}_{i\cdot})^2 / (q - 1)$ = Genotype Variance

$CV_i = (\sqrt{s_i^2}/y_{i.})\ 100$ = Coefficient of Variation (%)

$W_i^2 = \sum_j (yij - \bar{y}_{i\cdot} - \bar{y}_{\cdot j} + \bar{\bar{y}})$ = Ecovalence

$\sigma_i^2 = [p/(p-1)(q-1)]W_i - SSGE/(p-1)(q-2)(q-1)$ = Interaction variance

$b_i = [\sum_j (y_{ji} - \bar{y}_{i\cdot})(\bar{y}_j - \bar{\bar{y}})]/\sum(\bar{y}_{\cdot j} - \bar{\bar{y}})^2$ = Regression slope

$\delta_i^2 = [1/(q-2)]\ [(y_{ji} - \bar{y}_{i\cdot})^2 - b_i^2 \sum (\bar{y}_{\cdot j} - \bar{\bar{y}})^2]$ = Deviation mean square

$R^2 = [b_i^2 \sum_j (\bar{y}_{\cdot} - \bar{\bar{y}})^2] / \sum (\bar{y}_{ij} - \bar{y}_{i.})^2$ = Coefficient of determination

Recent yield stability study on lentil by Sabaghnia *et al.*, (2008) infers that it would be very difficult to get indirect response to selection over all of the lentil target population of environments from selection in a few environments ignoring the observed G x E interactions but this interaction makes the selection difficult for the best performing and most stable genotype and reduces the progress from selection in any one environment for a breeding programme. According to Eberhart & Russell (1966), the genotype is considered to be stable that indicates b_i value equal or close to 1. Similarly, Petersen (1989) advocated that genotype is said to be more stable that has regression slope (b) equal or very close to 1 minimizes rest of the statistics, except R^2, which ranges from 0 to 1, and its high value determines the stability of a genotype. Supported by the previous findings, the genotype NARC-06-1 with a slope of 1, a high mean yield (Table 1) with less statistics of variance, CV, ecovalence, interaction variance, deviation from regression and high value of R^2 can be considered a stable genotype to all environments. It is unique example that a genotype performed so well in all environments when evaluated for its stability using eight different statistical measures, it passed all the tests and proved to be a stable genotype. This kind of situation is seen when a genotype has a broad genetic base and widely adapted to various environments. The NARC-06-1 seems to be near to an ideotype that was not developed in Pakistan before. The both parents, ILL 7670 (ICARDA, Syria) and PI 339283 (Canadian origin), of NARC-06-1 were exotic. Those were evaluated before putting them into crossing scheme. All the desirable traits and needs of the country were kept in mind. The effort was to craft such genotype which could fit in our broad range of environments with high yield and keeping all other desirable traits for consumer preference intact. Furthermore, the genotypes possessing b value greater than 1 show adaptability in high-yielding or good environments and the genotypes having b_i value less than 1 have adaptability for low-yielding or poor environments (Petersen, 1989). The genotypes NARC-06-2, NARC-06-4, AEL-23/40 and 01512 gave above average yield (915 kg ha^{-1}) and having regression coefficient (b) greater than unity, indicating that these genotypes are suitable for high yielding or good environments only. On the other hand, the genotypes NL-96625, Masoor-93 and NIAB Masoor-06 gave below average yield and regression slope (b) values less than 1 may be considered suitable for poor or low yielding environments. This situation suggests that maximum statistical measures for yield stability should be adopted to maximize the confidence level before making final decision about the genotype to be released as a variety, the ultimate goal of any crop improvement programme.

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