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Quantitative evaluation of lentil (*Lens culinaris* Medikus.) germplasm under low-input acidic upland soil conditions of North-East India

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Abstract

The present investigation was carried out to assess genetic diversity in 88 lentil genotypes and to identify desirable genotypes under low-input acidic upland soil conditions. Shoot weight, number of pods/plant number of primary branches showed highest association with yield. All the lentil genotypes were grouped into eight distinct clusters. The maximum contribution towards divergence was due to seed thickness followed by plant height and root biomass. Principal components analysis performed on quantitative traits revealed that the first three most informative components accounted for 78.83% variance among the genotypes studied. Genotypes IPL-325, LRIC560812 and PL-04, were found suitable for low-input acidic upland conditions.

Key words: Lentil, soil acidity, diversity, evaluation

Introduction

Annual crop productivity in the North Eastern Region (NER) of India is low, primarily due to the non utilization of rice fallows during *rabi*. Lack of rainfall and irrigation, and acidic soils that are deficient in essential nutrients makes growing *rabi* crops economically unsustainable. Lentil (*Lens culinaris* Medikus) has great significance in cereal-based cropping systems because it fixes nitrogen. High protein contents and the straw makes it useful for hman food and animal feed. It is a major pulse crop grown in an area of 15 lakh hectares with a production of 9.5 lakh tonnes with productivity of 933.33 kg/ha in India [1]. In spite of being the most consumed pulse of the NER, lentil is cultivated sporadically on relatively poor soils and in harsh environments with a little or no fertilizer after rice crop. Such soils, especially under upland conditions are known to harbour high concentrations of Aluminium that is toxic to plants [2]. Therefore, there is a need for identifying lentil germplasm that is adapted to low input acidic soils to achieve remunerative productivity. It has been reported that the lentil varieties in India have a narrow genetic base and there is a need for incorporating diverse promising genotypes into breeding programmes [3]. The knowledge of degree of association of various agro-morphological characters with yield helps in designing effective breeding strategies for crop improvement. Moreover, traits such as root and shoot biomass have been reported to be associated with yield under drought and poor soils [4-6]. Therefore, this study was undertaken to understand and identify genotypes with high yield under low moisture and low input acidic soil conditions. The idenitifcaiton of such genotypes will facilitate design effective lentil breeding strategy for the region.

Materials and methods

A set of 88 lentil germplasm accessions from different parts of the country and ICARDA was tested under low-input acidic upland soil conditions during *rabi*, 2013. The accessions were sown in augmented design having 4 blocks with 22 genotypes in each block. Four checks NDL-1, PL-6, PL-8 and Moitree were replicated in each block. Plant to plant and row to row spacing was maintained at 10 and 20 cm, respectively. The field experiment was carried out with no nutrient input in the field, except incorporation of rice stubbles from the previous *kharif* season. The field soil pH was recorded from three randomly selected sites in the experimental plot at regular intervals during the crop growth season.

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Soil pH was found to be below five throughout the season (Fig. 1).

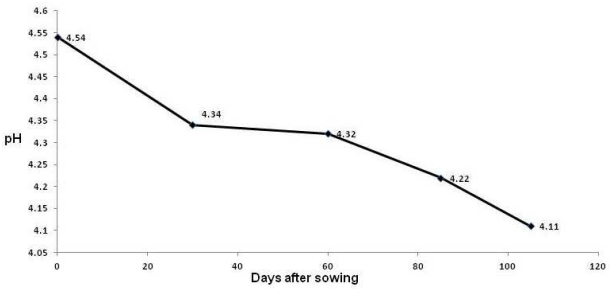

Fig. 1. Mean soil pH of the experimental plot taken at five different dates during the crop growth period

Morphological data were collected for eleven quantitative characters at the appropriate growth stages of lentil plant. The plot means were analysed using online data analysis software for augmented design hosted by Indian Statistical Research Institute, New Delhi (www.iasri.res.in/SpadWeb/). The correlation coefficient were estimated as suggested by Dewey and Lu [7]. The data were subjected to analysis of genetic divergence through D^2 statistic [8] to measure genetic divergence as suggested by Rao [9], while Tocher's method was used to form clusters. Principal component analysis (PCA), based on the all the 11 traits studied, was done by using XLSTAT software.

Results and discussion

Correlation analysis

In order to obtain the best combination of traits in lentil for enhancing yield under acidic soils, correlation coefficients among all traits were analysed to understand the degree of association between various traits and yield (Table 1). Previous studies have demonstrated the significance of traits like biological yield, harvest index, seedling vigour and root biomass under drought stress [5, 6]. As for the traits considered in this study, pod yield per plant showed strong correlation with shoot weight (r = 0.912), number of pods per plant (r = 0.976), number of primary branches (r = 0.853) and root weight (r = 0.649) indicating the importance of plant biomass accumulation under nutrient deficient acidic soil conditions. Significant positive correlation for root weight and shoot weight were found with number of pods per plant, pod weight per plant, number of primary branches, number of secondary branches and plant height. Also,

Table 1. Correlation coefficients among the eleven characters of Lentil

Variables	Shoot weight	Root weight	Plant height	Harvest index	No. of pods/plant	Pod weight/ plant	No. of primary branches	No. of secondary branches	100 seed weight	Seed diameter	Seed thickness
Shoot weight	**1**	0.682**	0.621**	0.146	0.898**	0.912**	0.778**	0.760**	-0.043	0.036	0.053
Root weight		**1**	0.395**	-0.018	0.654**	0.649**	0.624**	0.538**	0.038	0.095	0.095
Plant height			**1**	0.061	0.550**	0.564**	0.559**	0.583**	0.078	0.111	0.126
Harvest index				**1**	0.419**	0.418**	0.387**	0.290*	-0.253	-0.099	0.081
No. of pods per plant					**1**	0.976**	0.878**	0.788**	-0.058	0.017	0.046
Pod weight per plant						**1**	0.853**	0.770**	-0.033	0.063	0.060
Primary branches							**1**	0.774**	-0.063	-0.016	0.115
Secondary branches								**1**	0.064	0.130	0.215
100 seed weight									**1**	0.810**	0.316*
Seed diameter										**1**	0.413**
Seed thickness											**1**

(Significance Levels: 0.05= *; 0.01=**)

root weight had high significant correlation with shoot weight. A study in chickpea under similar soil conditions by Pandey *et al.* [10] reported significant correlation of grain yield with plant height, pods per plant and 100 seed weight. Seed size and seed diameter in lentil are known to be genotype specific traits. Interestingly, pod weight per plant and number of pods per plant were negatively correlated with 100 seed weight, seed diameter and seed thickness. Karakoy *et al.* [11] reported significant positive correlation between 100 seed weight and seed size. Similar correlation of seed thickness and diameter were found in earlier studies [12]. Contrary to the present findings result, Mondal *et al.* [13] reported that yield in lentil depends on seed size. Lentil seeds with small size are generally preferred for *dal* making purposes, therefore, non significant association of seed size and yield is desirable.

Genetic divergence analysis

Cluster analysis was performed to find out the extent of genetic diversity so that diverse cross combinations can be selected for future breeding programme. All the 88 lentil genotypes were grouped into eight clusters (Table 2) based on D^2 analysis. Maximum number of genotypes were retained in cluster I (62) followed by cluster III (12). Clusters IV, V, VII and VIII consisted of only one individual each. Highest inter-cluster distance was observed between Cluster II and cluster VII that consisted of IPL- 325 only, whereas highest intra-cluster distance was observed in cluster III. The maximum contribution towards divergence was due to seed thickness (15.13%) followed by plant height (13.58%) and root weight (12.07%) (Table 3). Cluster I exhibited maximum mean values for harvest index and minimum mean value for root weight. Cluster II had the highest mean value for harvest index followed by plant height. Cluster III had the highest mean value for harvest index and number of pods per plant. Similar divergence analyses in lentil have been reported [14-16]. However, this study focussed on identifying diverse genotypes based on morphological traits as expressed under acidic soil conditions. The results of D^2 analysis may be useful in identifying the best parental combination for generating variability with respect to various traits under

Table 2. Inter- and intra- (bold) cluster distances (D^2) and distribution of 88 genotypes of Lentil to different clusters

Clusters	I	II	III	IV	V	VI	VII	VIII	Genotypes
I	**0.12**	0.26	0.25	0.25	0.27	0.41	1.03	0.45	LRIC560181, LRIC560183, LRIC560297, LL-1210, PL-8, LH-07-27, LL-56, LRIC560228, L1112-19, LRIC560299, IPL-221, RLG-147, KLS113, HPLC-617, DL-10-1, L-4581, LRIC559890, WBL-81, KLS-314, NDL-11-1, KLS-345, L-4076, MOETRE, ASHA, L-4591, SUBRATA, L-4590, RANJAN, LRIC560206, KLS-107, LRIC560226, PL-406, LRIC560307, LRIC559924, LRIC560212, LRIC560182, PL-6, L1112-14, K-75, LRIC560343, L1112-7, LRIC569608, LRIC599831, LRIC560322, LL-1231, DPL-62, LL-1161, LRIC560040, LRIC560337, L1112-9, L1112-6, LRIC560008, LRIC559876, L1112-18, LRIC559996, LRIC560172, LRIC564169, LRIC560329, L1112-16, LRIC560173 and IPL-220
II		**0.12**	0.8	0.27	0.47	0.48	1.82	0.65	L1112-10, L1112-11, LRIC567318, LRIC560350, LRIC560335, L1112-8, LRIC560336 and LRIC564649
III			**0.21**	0.54	0.39	0.6	0.46	0.87	IPL-29 , PL-099, PL-101, IPL-220, IPL-322, IPL-324, LRIC560812, PL-04, PL-117, LH-08-10 and SKUAL-2-96
IV				**0**	0.07	0.14	1.12	0.59	LRIC560331
V					**0**	0.19	0.74	0.51	LRIC560185
VI						**0.07**	1.04	0.72	LIRC560169 and SKUAL-12-96
VII							**0**	1.52	IPL-325
VIII								**0**	LIRC560333

Table 3. Contribution of morphological characters towards divergence and their mean value in different clusters

S.No.	Traits	Contribution %	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII
1.	Shoot weight (g)	4.18	1.03	0.4	2.1	0.8	1.16	1	2.85	0.09
2.	Root weight (g)	12.07	0.23	0.15	0.43	0.16	0.22	0.39	0.44	0.04
3.	Plant height (cm)	13.58	14.02	12.16	17.14	14.66	17.86	14.83	23.01	12.81
4.	Harvest index	11.02	57.57	25.25	59.93	28.89	61.4	26.49	67.62	154.58
5.	No. of pods per plant	3.34	20.64	4.16	37.38	15.18	20.58	17.76	54.63	14.63
6.	Pod weight per plant (g)	3.08	0.81	0.21	1.48	0.64	0.92	0.72	2	0.61
7.	No. of primary branches	7.26	1.77	0.57	3.04	1.77	2.17	1.61	4.92	1.22
8.	No. of secondary branches	8.18	2.1	0.71	3.78	2.18	3.18	1.89	7.36	2.08
9.	100 seed weight (g)	11.13	2.44	2.74	2.52	4.37	4.6	4.89	3.2	3.12
10.	Seed diameter (mm)	11.02	0.43	0.44	0.45	0.6	0.6	0.63	0.55	0.5
11.	Seed thickness (mm)	15.13	0.25	0.25	0.26	0.25	0.25	0.31	0.3	0.3

study. For creating wide spectrum of variability and improving the grain yield the genotypes from clusters II, III and VI may be crossed with genotypes of cluster IV, V, VII and VIII since clusters IV, V, VII and VIII contained only one genotype and all these genotypes were suitable for most of the characters.

Principal component analysis and identification of desirable genotypes

We subjected the morphological data on 11 traits to PCA in order to visualize the spread of genotypes around the major eigen vectors. Many studies, including Smith *et al*. [17] that of who conducted average linkage cluster and principal component analysis, and reported the utility of these results in preservation and utilization of germplasm. The PCA performed on quantitative traits revealed that the first three most informative components accounted for 78.83% variance among 88 genotypes of lentil (Table 4). Number of pods per plant (0.413), pod yield per plant (0.412) and shoot weight (0.397) were the top contributors to the first principle component (PC1); while seed diameter (0.622), 100 seed weight (0.621), seed thickness (0.397) contributed to the second principle component (PC2). Also, harvest index (0.776), seed thickness (0.428), seed diameter (0.097) contributes to the third principle component (PC3). Better performing outliers with respect to the two principal components were identified. PCA helped in identifying genotypes IPL-325, LRIC 560812, IPL-324, LRIC 560185 and SKUAL-12-96 that were performing well with respect to both the principle components (Fig. 2). Moreover, we also identified contrasting parents for the traits of our interest (Table 5), crosses between which can be used for development of mapping populations. Recent mapping studies have focussed on seed characteristics [12], plant structure and growth habits [18], and with the availability of different maker based genotyping platforms in lentil, mapping populations for traits of interest could be a useful resource. The present study identified traits of importance and suitable genotypes like IPL-325, LRIC560812 and PL-04 that can be used directly as varieties for upland acidic soils, or can be crossed with diverse genotypes breeding high yielding and suitable

Table 4. Eigen values and percentage variability explained by the three most informative principal components and the top three morphological traits contributing towards them

Principal component	Eigen value	Variability (%)	Cumulative %	Traits		
				Rank 1	Rank 2	Rank 3
PC 1	5.422	49.295	49.295	No. of pods/plant (0.413)	Pod yield/plant (0.412)	Shoot weight (0.397)
PC 2	2.137	19.43	68.725	Seed diameter (0.622)	100 seed weight (0.621)	Seed thickness (0.397)
PC 3	1.112	10.107	78.832	Harvest index (0.776)	Seed thickness (0.428)	Seed diameter (0.097)

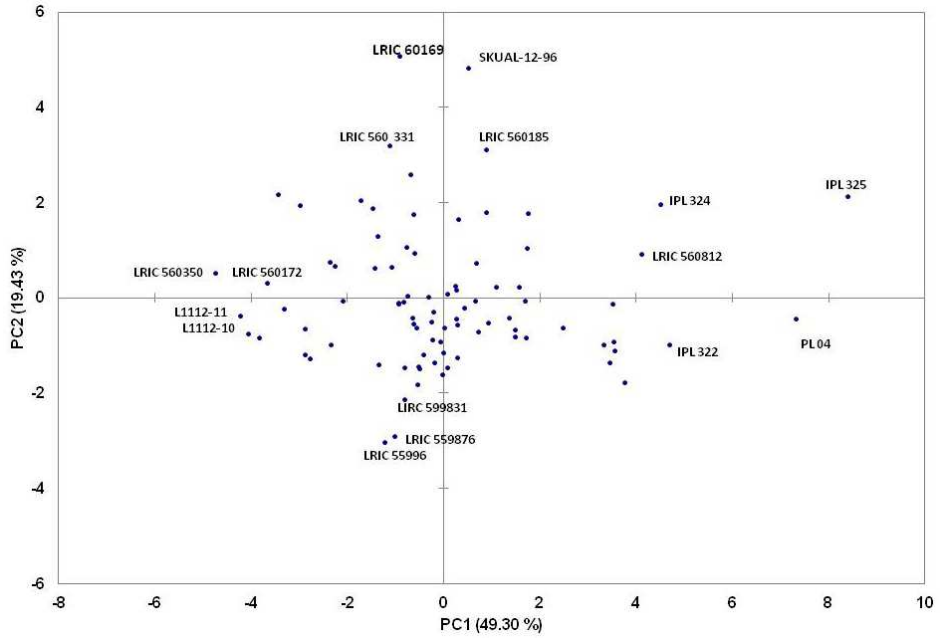

Fig. 2. Scatter Diagram showing distribution of lentil germplasm with respect to two principal components

Table 5. Identification of genotypes based on *per se* performance with respect to important traits

Traits	Highest	Lowest
Shoot biomass	PL-04	LRIC560331
	IPL-325	LRIC560329
	IPL-322	LRIC560172
Root biomass	SKUAL-2-96	LRIC560322
	PL-04	LRIC560331
	PL-101	LRIC560329
Pod yield per plant	LRIC560812	LRIC560172
	IPL-325	LRIC560331
	PL-04	LRIC560350
Seed Diameter	SKUAL-12-96	LRIC559876
	LRIC560331	LRIC569608
	LRIC560169	KLS-107
Seed thickness	SKUAL-12-96	IPL-220
	LRIC560169	LRIC569608
	LRIC560173	LRIC559876

genotypes for such nutrient deficity, marginal and low pH soil conditions.

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