Phenotypic characterization of lentil genotypes for P uptake and utilization efficiency at seedling stage

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Abstract

Phosphorus (P) is an essential, non-renewable nutrient for crop productivity worldwide. P is immobilized in the soil, which limits its uptake and utilization by the plants. Breeding for P uptake and utilization efficiency is the most sustainable strategy to employ available resources in the best possible way. The present study was carried out to identify P uptake and utilization efficient lines under low p condition at seedling stage in lentil. A set of diverse lentil genotypes (85) belonging to six different Lens species was screened under normal and low P condition in hydroponics under controlled environment. Significant reduction in root dry weight (RDW), shoot dry weight (SDW) and total dry weight (TDW) was evident under low P condition. Cluster analysis indicate that TDW, SDW and RDW were significantly correlated to P uptake efficiency (PupE) and P utilization efficiency (PutiE) in lentil. PupE ranged from 19.50 to 266.49 mg plant-1 under low P and PutiE ranged from 30.53% to 97.50%. Based on TDW under low P, EC718309, EC718348, and EC718332 were found promising for PupE while PL06 and EC718332 exhibited better PutiE. EC718332 was observed as efficient and responsive genotype for both P uptake and utilization. These identified genotypes can be used as trait donor for breeding lentil varieties for low P environment.

Introduction

- Lentil (*Lens culinaris Medikus ssp. culinaris*), is a self-pollinated legume with 4063 Mbp/1C genome size. (Arumuganathan and Earle, 1991).
- Presently, the crop is cultivated for protein rich seed and valuable straw in North America, South Asia, and the Mediterranean region (FAO, 2020).
- Phosphorus (P) is non-renewable and essential nutrient with limited global reserves. The use of phosphate fertilizers increased more than four times in past five decades and is expected to reach 22-27 mton /year by 2050 (Mogollon et al., 2018).
- Plants absorb P from the soil mainly in the form of soluble inorganic P. P availability is low due to its fixation with calcium in acidic soils and iron/aluminium in alkaline soils. Low P reduces crop yield by restricting the growth and development (Heuer et al., 2017).
- Improvement of P use efficiency (PUE) becomes more important in legumes as legumes require more external P for growth and development as compared to other crops. The P utilization efficiency (PutiE) can be increased by improving uptake/translocation and partitioning of P within the plant, whereas P uptake efficiency (PupE) can be increased by targeting root morphology, root system architecture and exudation properties (Kidd et al., 2015).
- Therefore the present research emphasize i) phenotypic characterization of genetic variation for morphological root and shoot traits in lentil, ii) identification of key root and shoot traits contributing for PutiE and PupE.

Methodology

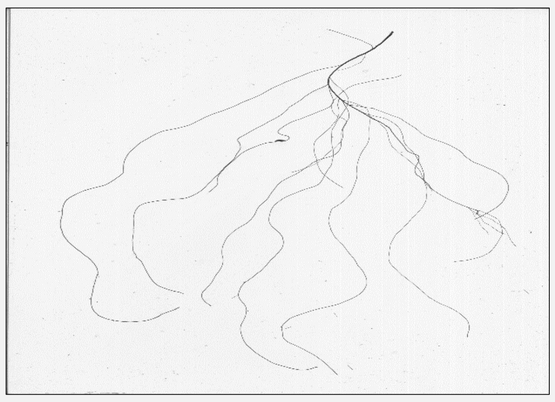
- The experiment was conducted under greenhouse with controlled environmental conditions at National Initiative on Climate Resilient Agriculture (NICRA)- controlled environment facility of the Indian Agricultural Research Institute, New Delhi, India 2019.
- The seeds were surface sterilized with 0.1% (w/v) HgCl2 for 3 min followed by double distilled water rinsing. The lentil seeds were scarified, wrapped in the germination paper and kept in dark for the germination. The 8-10 days old seedlings of uniform size were transferred to the Hoagland solution (Sivasakthi et al., 2017).
- The Epson professional WinRHIZO Pro 2016a software were used for scanning of root architecture system of lentil. root scanner. The root traits such as primary root length (PRL, cm), total root length (TRL, cm), total surface area (TSA, cm2), average root diameter (ARD, cm), total root volume (TRV, cm3), total root tips (TRT, cm), and root fork (RF) were measured. The shoot and root system of plants were oven dried at 65°C for 48 h to obtain shoot dry weight (SDW, mg plant-1), root dry weight (RDW, mg plant-1), total dry weight (TDW, mg plant-1), Root to Shoot ratio (RSR, mg mg-1).
- P concentration was estimated with diacid mixture (HNO3: HClO4, 9:4) (Murphy et al., 1969). The PupE and PutiE were calculated using the following formulas (Irfan et al., 2020; Neto et al., 2016)

  PupE (mg plant-1) = P concentration(mg mg−1) × dry matter(mg plant−1)

  PutiE (%) = TDW (LP)/TDW (SP) × 100
- The STAR (Statistical Tool for Agricultural Research) 2.1.0 analytical software and R software package “FactoMineR” were used for statistical analysis (Gulles et al., 2014).

Results and Discussion

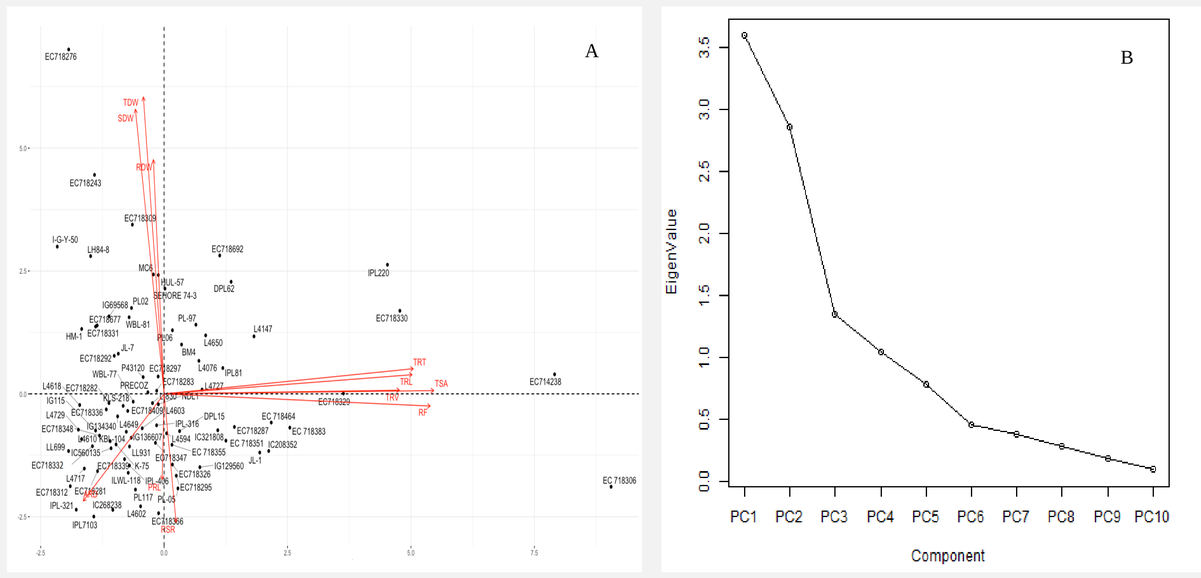
1. Phenotypic variation for shoot and root under SP and LP condition



2. Genetic variation in root and shoot traits under SP and LP

Traits	Max		Min		Mean		CV%		% change of mean
	SP	LP	SP	LP	SP	LP	SP	LP	
PRL	50.00	46.83	19.50	17.33	35.72	33.61	9.11	5.86	-5.91
TRL	1211.40	1380.41	43.42	80.44	366.79	418.34	10.68	8.61	14.05
TSA	171.87	133.05	9.45	9.08	59.02	48.57	10.26	9.62	-17.70
ARD	0.47	0.46	0.34	0.33	0.39	0.38	7.17	6.97	-2.56
TRV	1.80	1.35	0.10	0.08	0.52	0.47	11.14	13.72	-9.61
TRT	873.67	640.33	55.00	42.40	309.70	235.14	10.10	13.14	-24.07
RF	5630.67	1830.33	31.67	44.33	725.67	445.80	13.71	10.41	-38.57
SDW	260.00	163.33	78.89	55.56	148.65	89.76	12.60	13.61	-39.62
RDW	173.33	88.89	56.67	43.33	95.94	61.20	11.28	8.67	-36.21
TDW	424.44	235.56	151.11	103.33	244.59	149.84	11.35	10.26	-38.74
RSR	0.99	1.14	0.43	0.40	0.66	0.71	9.86	10.73	7.58
PupE	768.01	266.49	115.65	19.50	275.65	84.80	11.03	14.20	-69.23
PutiE	97.50		30.53		63.10		14.30		

3. Principal Component Analysis of Shoot and Root traits under LP



(A) Biplot (B) scree plot using relative values of tested root and shoot traits

4. Selected lentil genotypes belonging to top (8) 10% in TDW, SDW, along with same genotypes also being in top 10% for RDW, PupE and PutiE

Genotype	TDW	SDW	RDW	PupE	PutiE
L4727	•	•			
EC718309	•	•	•	•	
EC714238	•	•	•		
PL-97	•	•			
EC718348	•	•	•	•	
DPL15	•		•		
PL06	•	•	•		•
EC718332	•	•		•	•

Conclusion

The studied *Lens* genotypes exhibited significant phenotypic and genetic variability for different root and shoot traits at two contrasting levels of P. Most of the recorded parameters revealed remarkable reduction in P deficient conditions. The present study revealed that PupE and PutiE was associated with TDW, RDW, SDW and RSR in lentil. The genotypes (L4727, EC718309, EC714238, PL-97, EC718348, DPL15, PL06 and EC718332) were identified to be promising for dry weight along with PupE and PutiE. Further, carboxylation efficiency of identified lines needs to be explored to completely understand P use in lentil. EC718332 were found to be efficient in uptake as well as utilization of P under LP. Hence, these identified lines can be targeted as potential donors in breeding program for low P environments.

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