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Assessment of mungbean (*Vigna radiata* L.) cultivars in relation to phosphorus utilization efficiency under phosphorus stress environment

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ABSTRACT

The present study was conducted during kharif season of 2019 with 24 diverse mungbean cultivars under the hydroponic system at the Indian Agricultural Research Institute, New Delhi to assess the phosphorus utilization efficiency of genotypes under a phosphorus stress environment. Cultivars differed significantly for biomass accumulation, P concentration, total P uptake and PUtE. Categorization based on PUtE and total dry weight, cultivars MH 521, MH 805 and PM 5 were identified as efficient and responsive (ER) under LP condition. The phosphorus stress factor values indicated the varied response of cultivars to P stress. The identified efficient genotypes could be used in themungbean breeding programme for P efficiency improvement.

Key words: Mungbean, PSF, PUtE, TDW, phosphorus stress environment

INTRODUCTION

Mungbean (*Vigna radiata*L.) is an annual, herbaceous and fast growing legume crop. In India, it is the third most important legume crop cultivated in the area of 4.26 m ha with a production of 2.41 m tones during 2019-20. In India, major growing states of mungbean are Andhra Pradesh, Bihar, Gujarat, Karnataka, Maharashtra, Orissa, Rajasthan, Tamil Nadu, Telangana and Uttar Pradesh. Mungbean can be grown as a catch crop due to its fast maturity. Mungbean seeds can be utilized in making dhal, soups, curries and sweets. The germinated mungbean seeds are the richest source of nutrients and are used as a fresh salad in India and South East Asia. Mungbeans mainly contain vitamins, minerals along with proteins (25-28%), carbohydrates (62-65%), fiber (4.5-5.5%) and oils (3.5-4.5%). Phosphorus is the second most important macronutrient limiting for crop growth after nitrogen. Phosphorus mainly plays an important role in physiological activities including sugar metabolism, enzymatic reaction, energy metabolism and photosynthesis. In plants, P deficiency mainly leads to dark green foliage, high root to shoot ratio, stunted growth and delayed maturity of plants (Malhotra *et al.*, 2018). In soil, the large amount of P is fixed in the form of organic P fractions or inorganic complexes with aluminium/iron in acid soils or with calcium in alkaline soils. So in most of the soils, P is least mobile and less available to plants. However, P limitation is overcome by applying P fertilizers to the soils. The main source of P fertilizer is rock phosphate, which is minable only in a few countries of the world. So by expecting future scarcity, it is time to think about the development of phosphorus use efficiency (PUE) of crop plants by using plant breeding approaches.PUE depends on the complex set of plant traits and can be differentiated into uptake and utilization efficiencies. P uptake efficiency refers to the amount of P uptake by the plant. Whereas utilization efficiency refers to the amount of biomass produced per unit P uptake by plants. For P, external application of P fertilizer is the main option (Singh *et al.* 2021). To avoid this, the development of cultivars with improved ability to absorb more P and their efficient utilization is one of the ways to solve the problem sustainably. In India, except for some isolated efforts, none of the research programmes generated information on the P use efficiency of cultivars in the mungbean. The present study was aimed to determine the genotypic variability of mungbean cultivars in response to P levels and exploitation of genetic variability to identify efficient mungbean cultivars in relation to P efficiency.

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MATERIALS AND METHODS

The experiment was conducted using 24 diverse mungbean cultivars namely BMGP 1, DMS 10,DMS 4, EC 398885, EC 520034, HUM 12, IC 436636, KM 11-10, KM 12-29, KPS 3, MH 421, MH 521, MH 805, ML 1451, ML 1666, ML 512, PM 5, PUSA 0672, PUSA 105, PUSA 831, PUSA 9072, PUSA 9531, SM 11-75 andSML 1815. The present investigation was carried out in greenhouse condition at the Indian Agricultural Research Institute, New Delhi during kharif season of 2019. Initially, seeds of all 24 cultivars were sterilized with mercuric chloride (0.1% w/v) and kept for germination. After germination, uniform seedlings were transferred to hydroponic trays with a modified Hoagland solution. The composition of nutrient solution was used as $MgSO_4$ (1 mM), K_2SO_4 (0.92 mM), $CaCl_2.2H_2O$ (0.75 mM), Fe-EDTA (0.04 mM), urea (5 mM), and micronutrients [H_3BO_3 (2.4 µM), $MnSO_4$ (0.9 µM), $ZnSO_4$ (0.6 µM), $CuSO_4$ (0.62 µM), and Na_2MoO_4 (0.6 µM) (Sivasakthi*et al.*, 2017). The control and treatment conditions of P stress were maintained with two levels of P i.e. normal P (NP) (250µM) and low P (LP) (3µM) (Reddy *et al.*, 2020). The nutrient solution was replaced every two days interval and the pH of the solution was maintained at 6.0.

On the 21st day, the seedlings were removed from hydroponic trays. The root and shoot portions were separated in all the seedlings and kept for drying at 60ºC in a hot air oven. After obtaining constant mass, root dry weight (RDW), shoot dry weight (SDW) were estimated by using precision weighing balance. Then RDW and SDW estimates were used to calculate root to shoot ratio (RSR) and total dry weight (TDW). The P concentration (P CON) (mg P/ g dry weight) of dried samples was estimated by digesting the samples with the di-acid mixture (9:4 ratio of nitric acid and perchloric acid) followed by the method described by Murphy and Riley (1962). Total P uptake (TPUP) (mg P/plant) was calculated by multiplying P CON with TDW of the plant. The P utilization efficiency (PUtE) of cultivars was estimated as per formula of Reddy *et al.* (2021). The P stress factor (PSF) was estimated as per the formula of Irfan *et al.* (2017). For the categorization of cultivars, the two variables were plotted for each cultivar. On Y-axis PUtE and on the X-axis TDW were plotted. The mean values of variables were used to divide the cultivars into four groups i.e. efficient and responsive (ER), inefficient and responsive (IR), efficient and non responsive (ENR) and inefficient and non responsive (INR). Data were exposed tothe analysis of variance for each investigated trait under both P levels. Descriptive statistics, Coefficient of variation and broad sense heritability of traits were estimated by using the software STAR (Statistical tool for Agricultural Research) 2.1.0 software (Gulles *et al.*, 2014). The ordination plots for the categorization of cultivars were developed with the MS-EXCEL programme.

RESULTS AND DISCUSSION

The data (Table 1) showed that the mean values of RDW, RSR were higher under the LP condition compared to the NP condition. Whereas SDW, TDW, P CON, TPUP mean values were high under NP condition indicating the response to different P levels. A similar type of results was observed in mungbean (Pandey *et al.*, 2014). For PUtE, mean values were recorded high under LP condition. The maximum PUtE values were found under LP conditions only. The coefficient of variation ranged from 10.00 to 31.07 % and 8.56 to 14.36% under LP and NP conditions, respectively. The broad sense heritability of RDW i.e. 0.93 and 0.94 was found to be highest among the investigated traits under LP and NP conditions, respectively. The PSF value ranged from -23.14 to 28.91 with a mean value of 6.26 and a standard deviation of 14.34.

The mungbean cultivars showed a wide range of variation for TDW under NP and LP conditions. The TDW value ranged from 0.097 to 0.249 (g/plant) and 0.107 to 0.277 (g/plant) under NP and LP conditions, respectively (Table 2). The high TDW was recorded by MH 421 (0.249 g/plant) and PUSA 9531 (0.277 g/plant) under NP and LP conditions, respectively. Whereas low TDW was recorded by EC 398885 (0.097) and DMS 10 (0.107 g/plant) under NP and LP conditions, respectively. This indicates the wide variation of cultivars for TDW in response to P deficiency in mungbean. In soybean, higher P application significantly increased the whole plant dry weight than normal and low P application (Taliman *et al.*, 2019).

Table 1: Descriptive statistics of P efficiency traits in mungbean genotypes under low P (LP) and normal P (NP) conditions

Traits	P level	Mean	SD	Maximum	Minimum	CV	h^2
RDW (g)	LP	0.055	0.025	0.113	0.020	11.30	0.93
	NP	0.031	0.009	0.045	0.020	14.30	0.94
SDW(g)	LP	0.126	0.029	0.170	0.067	12.75	0.70
	NP	0.162	0.036	0.213	0.077	9.02	0.86
RSR	LP	0.436	0.163	0.747	0.227	14.52	0.86
	NP	0.195	0.040	0.265	0.122	14.35	0.63
TDW(g)	LP	0.181	0.049	0.277	0.107	10.00	0.88
	NP	0.194	0.043	0.249	0.097	8.56	0.85
P CON(mg P/ g dry weight)	LP	2.034	0.757	3.600	0.660	16.88	0.82
	NP	7.443	1.160	9.660	5.115	10.21	0.67
TPUP (mg P/plant)	LP	0.375	0.202	0.893	0.115	16.66	0.91
	NP	1.446	0.410	2.340	0.513	14.36	0.78
PUTE (g/ dry weight/ mg P)	LP	0.603	0.341	1.687	0.279	31.07	0.75
	NP	0.139	0.024	0.198	0.107	10.15	0.71
PSF		6.263	14.345	28.906	-23.140		

RDW, root dry weight; SDW, shoot dry weight; RSR, root to shoot ratio; TDW, total dry weight; P CON, phosphorus concentration; TPUP, total phosphorus uptake; PUTE, phosphorus utilization efficiency; PSF, phosphorus stress factor; SD, standard deviation; CV, coefficient of variation; h^2, broad sense heritability

A similar type of results was reported in chickpea (Habibzadeh, 2015). For TPUP, the highest and lowest values were recorded by PUSA 105 (2.34 mg P/plant) and EC 398885 (0.51 mg P/plant) under NP condition, PUSA 0672 (0.89 mg P/plant) and ML 1666 (0.12 mg P/plant) under LP condition, respectively. Generally genotypes with high RDW, SDW and TDW showed higher P uptake in their plant parts. Among the investigated cultivars, the highest PUtE was recorded by MH 521 under both NP (0.198 g DW/mg P) and LP (1.687 g DW/mg P) conditions. The lowest value of PUtE was recorded by PUSA 105 (0.107 g DW/mg P) under NP condition, PUSA 0672 (0.279 g DW/mg P) under LP condition, respectively. A higher P utilization efficiency mainly results from a higher yield per unit P uptake and P harvest index. This indicates the selection of one trait will not affect the other. The highest and lowest values for PSF were recorded by PUSA 9072 (-23.14%) and SM 11-75 (28.91%), respectively. PSF was mainly used to assess the relative tolerance of mungbean cultivars to low P stress condition.

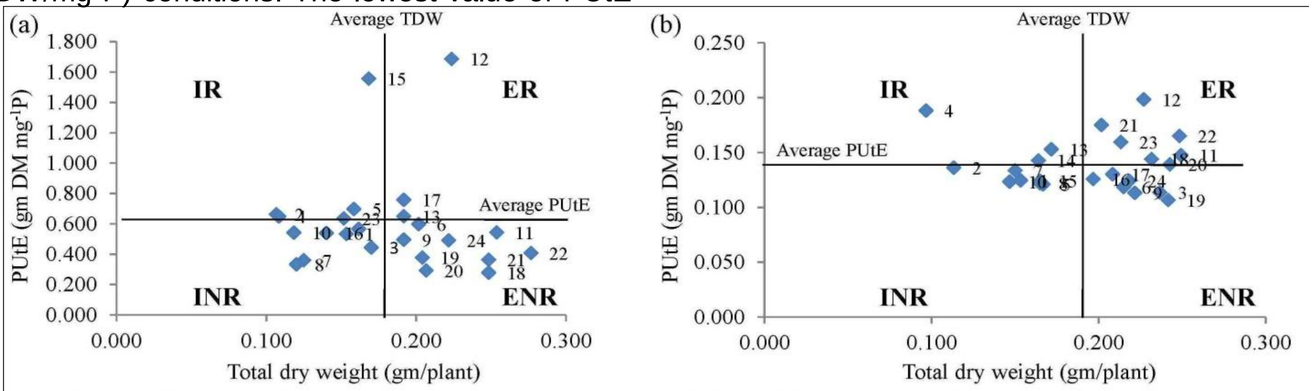

Fig. 1. Classification of genotypes based on P utilization efficiency (PUtE) and total dry weight (TDW) at (a) low P and (b) normal P levels.

The investigated mungbean cultivars were classified into four groups under both NP and LP conditions (Fig. 1). Under LP condition, MH 521, MH 805 and PM 5 were classified in ER group. Cultivars MH 421, MH 521, PUSA 0672, PUSA 831, PUSA 9072, PUSA 9531, SM 11-75 were classified in ER group under NP condition. The cultivars categorized under ER group are highly efficient and responsive by producing a high dry weight at low P than other cultivars

(Azizet *al.*, 2011). Further, cultivars BMGP 1, IC 436636, KM 11-10, KPS 3 and ML 512 were grouped in the INR category under LP condition. Whereas under NP condition, genotypes BMGP 1, DMS 10, EC 520034, IC 436636, KM 11-10, KPS 3 and ML 1666 were categorized in the INR group. Interestingly, genotype MH 521 was categorized in ER group under both P conditions. While genotypes BMGP 1, IC 436636, KM 11-10 and KPS 3 were categorized in the INR group under both P conditions. The performance of genotypes at both P levels is very important as the response of genotypes will vary with different P concentrations. Similar type categorization was used in wheat and identified the genotypes classified in ER group under both deficient and adequate P conditions (Bilal *et al.*, 2018).

Table 2: Mean values of 24 mungbean genotypes for total dry weight (TDW), total P uptake (TPUP), P utilization efficiency (PUtE) and P stress factor (PSF) under low P (LP) and normal P (NP) conditions

Genotypes	TDW (g)		TPUP (mg P/plant)		PUTE(g/ dry weight/ mg P)		PSF
	LP	NP	LP	NP	LP	NP	
BMGP 1	0.153	0.153	0.296	1.230	0.533	0.125	12.500
DMS 10	0.107	0.113	0.165	0.833	0.663	0.136	7.143
DMS 4	0.170	0.237	0.383	2.087	0.445	0.114	45.763
EC 398885	0.108	0.097	0.170	0.513	0.648	0.188	13.043
EC 520034	0.158	0.167	0.227	1.378	0.699	0.121	18.605
HUM 12	0.202	0.215	0.344	1.815	0.599	0.119	23.529
IC 436636	0.125	0.150	0.348	1.123	0.360	0.134	25.641
KM 11-10	0.120	0.165	0.361	1.349	0.334	0.122	30.000
KM 12-29	0.192	0.222	0.387	1.959	0.495	0.113	26.316
KPS 3	0.118	0.147	0.218	1.191	0.543	0.123	23.684
MH 421	0.254	0.249	0.470	1.696	0.543	0.147	19.431
MH 521	0.224	0.227	0.147	1.163	1.687	0.198	13.919
MH 805	0.192	0.172	0.297	1.120	0.650	0.153	25.000
ML 1451	0.162	0.164	0.302	1.148	0.566	0.143	10.448
ML 1666	0.168	0.165	0.115	1.328	1.557	0.124	11.905
ML 512	0.140	0.197	0.290	1.604	0.540	0.126	33.333
PM 5	0.192	0.208	0.254	1.600	0.759	0.130	16.667
PUSA 0672	0.248	0.232	0.893	1.619	0.279	0.144	10.714
PUSA 105	0.204	0.242	0.551	2.340	0.378	0.107	38.983
PUSA 831	0.207	0.243	0.722	1.838	0.293	0.139	35.919
PUSA 9072	0.248	0.202	0.684	1.157	0.364	0.175	0.000
PUSA 9531	0.277	0.248	0.686	1.504	0.409	0.165	23.438
SM 11-75	0.152	0.213	0.239	1.338	0.635	0.160	38.596
SML 1815	0.222	0.218	0.454	1.759	0.492	0.124	10.909

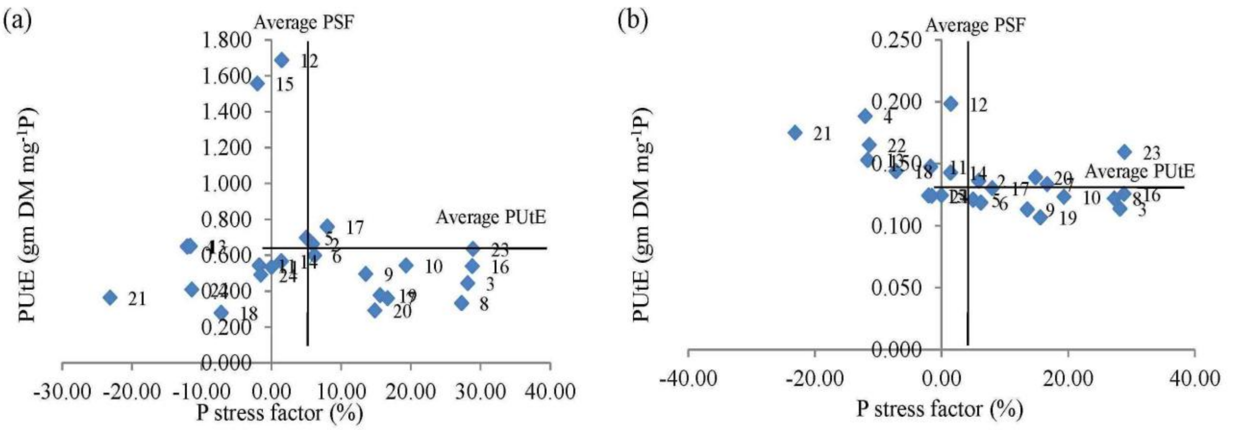

Fig. 2. Classification of genotypes based on P utilization efficiency (PUtE) and P stress factor (PSF) at (a) low P and (b) normal P levels

The cultivars were classified using PUtE and PSF (Fig.2). PSF mainly indicates the relative reduction in TDW due to P stress. Based on this classification, genotypes MH 521 under LP condition and PUSA 9072, MH 521 and ML 1666 under NP condition were found to be efficient. Interestingly, the cultivar MH 521 was found to be efficient under both P conditions. The genotype MH 521 was found to be efficient using both types of categorization methods under LP condition. The genotype PUSA 9072 recorded low PSF values under both LP and NP conditions. P stress factor as the measurement for assessing the P deficiency tolerance was used in mungbean (Irfan *et al.*, 2017). Since PSF is mainly used to assess the relative reduction in dry weight under treatment compared to control, it cannot be used as the sole criteria for the selection of cultivars under the P stress condition.

From this study, it may be concluded that the genotypes revealed a wide range of variability for accumulation of biomass, P uptake and P utilization efficiency under both LP and NP conditions. Cultivars showed a capricious response in terms of the P stress factor. The cultivars with higher dry weight generally showed high P uptake and P utilization efficiency. The genotype MH 521 showed efficient and responsive to both P conditions. Among the all tested cultivars three cultivars MH 521, MH 805 and PM 5 were found to be efficient and responsive under LP condition. Further, these efficient cultivars tested under a hydroponic system need to be validated under field conditions.

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