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The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(2): 937-941

www.thepharmajournal.com
Received: 03-11-2021
Accepted: 10-12-2021

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Study of genetic variability parameters and character association of seedling traits for seed yield in Mungbean [*Vigna radiata* (L.) Wilczek] under controlled conditions

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Abstract
A laboratory experiment was conducted to study genetic variability parameters and character association for seedling traits with 35 genotypes of mungbean under laboratory conditions at 30 °C and 40 °C temperature regimes during 2020 at College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner (Rajasthan). Highly significant differences were found among genotypes for all seedling traits studied except seed germination at 30 ^{0}C temperature which indicates the existence of ample amount of genetic variability among genotypes and therefore, signifying the scope of selection for genetic improvement of mungbean. Seedling traits like seedling dry weight, seedling fresh weight and seedling vigour index exhibited high degree of genetic variability along with high heritability and high genetic advance as per cent of mean at 40 °C. Therefore, screening of genotypes on the basis of seedling traits may be conducted at 40 °C. Among seedling traits, seedling fresh weight, seedling dry weight and seedling vigour index had positive correlation with seed yield at 30 °C and directly contributed towards seed yield.

Keywords: Mungbean, seedling traits, variability parameters, character association

Introduction
Mungbean is also known as green gram, an ancient pulse crop widely cultivated under different agro-ecological situations in India mainly during *Kharif* and summer seasons. It is a diploid species having chromosome number (2n=22) belongs to family Leguminosae (Fabaceae), sub-family Papilionaceae and is botanically recognized as *Vigna radiata* (L.) Wilczek. Mungbean is a native of South Asia (India). *Vigna radiata* var. *sublobata* is the probable progenitor of mungbean. It is essentially a self-pollinated crop (Singh *et al.*, 2015) [13]. Genetic variability is the foundation of plant breeding. Therefore, it is imperative to screen diverse genotypes for higher seed yield and component traits under high temperature stress. The identification of tolerant genotypes will help to further transfer this tolerance in high yielding varieties through appropriate breeding methods. The germination of seeds under controlled conditions offers effective confirmation of field screening. This additional support of field screening validates high temperature tolerant genotypes.
The estimation of genetic variability parameters like GCV, PCV, heritability and genetic advance are important for effective selection as well as upgrading of the breeding population. Correlation measures the degree and direction of association and also the genetic or non-genetic relationship between two or more traits which forms the basis for selection. Path analysis splits the correlation coefficient into the measures of direct and indirect effects of a set of independent variables on the dependent variable (Dewey and Lu, 1959) [6]. Therefore, the present study was conducted to assess genetic variability, heritability, genetic advance, correlation and path coefficient in mungbean for seedling traits.

Material and Methods
The experimental material consisting of thirty five genotypes/ varieties were procured from NBPGR, Regional Station, Jodhpur; Rajasthan Agricultural Research Institute, Durgapura, Jaipur; Agricultural Research Station, Sriganganagar and Agricultural Research Station, Mandor, Jodhpur is given in Table-1.

For seed germination, ten seeds of each thirty five mungbean genotypes were germinated at different temperature gradient (30 °C and 40 °C). The experiment was conducted in completely randomized design (CRD) with three replications of each genotype. The experiment was performed in plant growth chamber on seed germination paper (Gsm: 145) in petri-dish, which was made moist and was kept at different temperature gradients (30 °C and 40 °C). Glass petri-dishes (9 cm in diameter) were used for conducting the experiment. Germination papers were used as a matrix for seed germination. Ten disinfected or sterilized seeds of each thirty five mungbean genotypes were placed on sterilized seed germination papers in petri-dishes in plant growth chamber. Each germination paper was placed on petri-dishes which were moistened with 3 ml of double distilled water. Seed germination was recorded on 7th day of seed planted.

For seedling parameters, ten seeds of each thirty five mungbean genotypes were sown in 200 ml volumetric pot-tray containing solarite in plant growth chamber at different temperature gradient (30 °C and 40 °C). The experiment was conducted in completely randomized design (CRD) with three replications of each genotype. Observations were recorded for different seedling characteristics on 15th day of seed planting. Five seedlings were randomly selected from each pot-tray to record the data on seedling length, seedling fresh weight, seedling dry weight and seedling vigour index. The data on seedling dry weight was recorded after drying in hot air oven for 48 hours at 65 ^{0}C. The observations were recorded for following characters:

1. Germination (%): The qualitative germination capacity of seed based on binary answer (germinated and non-germinated) was converted into quantitative attribute as germination per cent. Ten seeds of each genotype were used to calculate germination per cent as the number of seeds germinated to total number of seed used in germination test at different temperature (30°C and 40°C). A seed was considered to have germinated at the emergence of both radicle and plumule up to 2 mm length (Chartzoulakis and Klapaki, 2000) [4]. The number of germinated seeds was recorded 7th day after planting in petri-dishes and the germination percentage was determined by using the following formula (Aniat *et al.*, 2012) [2]:

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds planted}} \times 100$$

2. Seedling length (cm): The seedling length of germinated seeds was recorded on the 15th day of planting in pot trays. Five seedlings from each genotype that was grown in the pot tray were randomly selected from each replication. The seedling length (the distance from root tip to shoot tip) was measured by using a measuring scale in centimetres and averaged.

3. Seedling fresh weight (mg): The fresh weight of seedling from the five seedlings which were selected already from each replication was measured in milligram by using a sensitive electronic balance and averaged.

4. Seedling dry weight (mg): The seedlings which were taken for fresh weight were kept into paper bags. The abbreviations of varieties were written on paper bags by the marker for further identification. After taking the fresh weight of seedlings these were kept in the oven at 65 ^{0}C for 48 hours for drying. After drying, the dried seedlings were weighed using the sensitive electronic balance in milligram and the average was recorded.

5. Seedling vigour index: The seedling vigour index was determined by multiplying the seedling length with concerned germination percentage by the following formula (Iqbal and Rahmati, 1992) [8]: Seedling vigour index = Seedling length (cm) X Germination percentage

Analysis of variance was done by subjecting the data to the statistical method described by Panse and Sukhatme (1985) [12]; Singh and Chaudhary (1985) [14]. Genotypic variances and phenotypic variances were calculated according to Johnson *et al.*, (1955) [9]; Comstock and Robinson (1952) [5], respectively from the expectations of mean squares by using an ANOVA table for each character. Heritability in a broad sense was calculated as suggested by Burton and Devane (1953) [3]. The expected genetic advance for each character was calculated as suggested by Johnson *et al.*, (1955) [9]. Phenotypic and genotypic correlation and path coefficients of variation were computed as per the method given by Dewey and Lu (1959) [6].

Result and Discussion

The analysis of variance revealed significant differences among thirty five genotypes of mungbean for all ten seedling traits except germination at 30°C which indicate the presence of good amount of variability in the genotypes and scope of selection for genetic improvement of mungbean (Table-2). The results confirmed the findings of Adlan (2019) [1] in mungbean, Get *et al.* (2019) [7] in lentil, Pal *et al.* (2020) [11] and Meena (2021) [10] in mothbean.

GCV and PCV estimates were high for seedling dry weight at 40 °C, seedling fresh weight at 40 °C and seedling vigour index at 40 °C. Therefore, high degree of heritable genetic variability in these seedling traits reveals the good scope of selection for these traits. Moderate GCV and PCV were estimated for seedling length at 40 °C, seedling dry weight at 30 °C and seedling fresh weight at 30 °C; whereas, it was found low for germination percentage at 40 °C and seedling vigour index at 30 °C (Table-3). Similar findings were earlier reported by Adlan (2019) [1] in mungbean and Get *et al.* (2019) [7] in lentil.

High heritability coupled with high/moderate genetic advance as per cent of mean were estimated for seedling dry weight at 40 °C, seedling fresh weight at 40 °C, seedling vigour index at 30 °C, seedling vigour index at 40 °C, seedling length at 40 °C, seedling fresh weight at 30 °C, seedling dry weight at 30 °C, seedling length at 30 °C and germination percentage at 40 °C which reveals that these characters were under the control of additive gene action. These results are accordance with the earlier finding of Adlan (2019) [1] in mungbean, Get *et al.* (2019) [7] in lentil, Pal *et al.* (2020) [11] and Meena (2021) [10] in mothbean.

Character association analysis specify that seedling length, seedling fresh weight, seedling dry weight & seedling vigour index at 30 ^{0}C and seedling dry weight at 40 ^{0}C had significantly positive correlation; however, seedling length, seedling fresh weight and seedling vigour index at 40 ^{0}C had significantly negative correlation with seed yield (Table-4). Path analysis reveals that the highest positive direct effect on seed yield per plant was observed for seedling vigour index at

30^0C followed by seedling dry weight at 40^0C, seedling dry weight at 30^0C, seedling length at 40^0C, seedling fresh weight at 30^0C and germination percentage at 40^0C at phenotypic level (Table-5). These findings are in accordance as reported by Adlan (2019) [1] in mungbean, Pal *et al.* (2020) [11] and Meena (2021) [10] in mothbean.

Table 1: Details of mungbean genotypes used in investigation

S. No.	Name of genotype	Year of Collection	Source of procurement
Germplasm procured from NBPGR, Regional Station, Jodhpur			
1	IC-39269	1993	Jodhpur, Rajasthan
2	IC-39300	1993	Jaswasar, Bikaner,Rajasthan
3	IC-39328	1993	Lalela, Barmer, Rajasthan
4	IC-39352	1993	Manduwa, Barmer, Rajasthan
5	IC-39399	1993	Jaspura, Palanpur, Gujarat
6	IC-39409	1993	Kapara, Banaskantha, Gujarat
7	IC-39454	1988	Surendranagar, Gujarat
8	IC-39492	1988	Dudhai, Mahesana, Gujarat
9	IC-39608	1992	Nevra, Jodhpur, Rajasthan
10	IC-39610	1992	Osian, Jodhpur, Rajasthan
11	IC-52076	1992	*
12	IC-52081	1992	*
13	IC-52082	1992	*
14	IC-52087	1992	*
15	IC-102792	1986	Banar, Jodhpur, Rajasthan
16	IC-102821	1986	Gidani, Jaipur, Rajasthan
17	IC-102857	1986	Khasur, Dholpur, Rajasthan
18	IC-103014	1986	Alampur, Kheda, Gujarat
19	IC-103059	1986	Krakas, Amreli, Gujarat
20	IC-103244	1986	Bhrwasa, Didwana, Nagaur, Raj.
21	IC-338868	1990	Sanari, Barmer, Rajasthan
Varieties/ genotypes procured from Agriculture University, Jodhpur			
22	Sweta		CSAVAT, Kanpur
23	IPM-02-3		ICAR-IIPR, Kanpur
24	IPM-02-14		ICAR-IIPR, Kanpur
25	Samrat (PDM-139)		ICAR-IIPR, Kanpur
26	GM-4		AAU, Pulse Res.Station,Vadodara
27	MH 2-15		CCSHAU, Hisar
28	MH-421		CCSHAU, Hisar
Varieties/ genotypes procured from RARI, Durgapura, Jaipur			
29	RMG-62		SKRAU-ARS, Durgapura, Jaipur
30	RMG-344		SKRAU-ARS, Durgapura, Jaipur
31	Keshwanand Mung-1 (RMG-975)		SKNAU-RARI, Durgapura, Jaipur
Varieties/ genotypes procured from ARS, Sriganganagar			
32	SML-668		PAU, Ludhiana
33	SML-832		PAU, Ludhiana
34	Ganga-1		SKRAU-ARS, Sriganganagar
35	MUM-2		CCS Meerut University, Meerut

*Source was not mentioned by NBPGR, Regional Station, Jodhpur.

Table 2: Analysis of variance of mungbean genotypes for seedling characteristics

S. No.	Character	Sources of variation		
		Replications	Genotypes	Error
	d. f.	2	34	68
1.	Germination percentage at 30°C	1.409	2.185^{NS}	1.703
2.	Germination percentage at 40°C	15.238	176.863**	23.081
3.	Seedling length (cm) at 30°C	0.224	4.686**	0.338
4.	Seedling length (cm) at 40°C	0.164	5.112**	0.110
5.	Seedling fresh weight (mg) at 30°C	109.189	2489.029**	79.682
6.	Seedling fresh weight (mg) at 40°C	4.732	2164.441**	6.088
7.	Seedling dry weight (mg) at 30°C	2.800	49.184**	1.661
8.	Seedling dry weight (mg) at 40°C	0.275	219.137**	0.281
9.	Seedling vigor index at 30°C	50.467	51326.178**	404.447
10.	Seedling vigor index at 40°C	975.705	47247.928**	652.325

*Significant at P = 0.05, ** Significant at P = 0.01; NS= Non-significant

Table 3: Genetic variability parameters of mungbean genotypes for seedling characteristics

S. No.	Characters	Mean	Range	Coefficient of variation		Heritability % (broad sense)	Genetic advance 5%	Genetic advance as per cent mean 5%
				Genotypic	Phenotypic			
1.	Germination per cent at 30 °C	99.68	96.67-100	0.51	1.29	15.66	0.42	0.42
2.	Germination per cent at 40 °C	85	67-100	8.39	9.00	86.90	13.75	16.12
3.	Seedling length (cm) at 30 °C	18.48	15.77-21.25	6.52	6.76	92.80	2.39	12.93
4.	Seedling length (cm) at 40°C	6.53	4.25-9.79	19.79	20.00	97.80	2.63	40.32
5.	Seedling fresh weight (mg) at 30 °C	270.18	215.56-385.87	10.49	10.66	96.80	57.44	21.26
6.	Seedling fresh weight (mg) at 40 °C	111.64	52.33-148.35	24.03	24.06	99.70	55.18	49.43
7.	Seedling dry weight (mg) at 30 °C	32.57	22.02-43.47	12.22	12.43	96.60	8.06	24.75
8.	Seedling dry weight (mg) at 40 °C	14.12	3.53-35.33	60.49	60.53	99.90	17.58	124.53
9.	Seedling vigor index at 30 °C	1839	1558-2125	7.08	7.11	99.20	267.33	14.54
10.	Seedling vigor index at 40 °C	561.56	355.83-819	22.19	22.35	98.60	254.95	45.40

Table 4: Estimates of phenotypic and genotypic correlation coefficient of mungbean genotypes for seedling characteristics

Character		Germination percentage at 30 °C	Germination percentage at 40 °C	Seedling length at 30 °C	Seedling length at 40 °C	Seedling fresh weight at 30 °C	Seedling fresh weight at 40 °C	Seedling dry weight at 30 °C	Seedling dry weight at 40 °C	Seedling vigor index at 30 °C	Seedling vigor index at 40 °C	Seed yield per plant
Germination percentage at 30 °C	P	1.000	0.287**	0.236*	0.059	0.080	0.046	0.119	0.020	0.392**	0.188	-0.009
	G	1.000	-0.940	-0.874	-0.143	-0.061	-0.150	-0.388	-0.057	-1.412	-0.662	-0.068
Germination percentage at 40 °C	P		1.000	0.363**	0.095	0.045	-0.086	-0.048	0.108	0.379**	0.483**	-0.096
	G		1.000	0.394	0.100	0.050	-0.094	-0.043	0.112	0.408	0.510	-0.102
Seedling length at 30 °C	P			1.000	-0.123	0.518**	-0.253**	0.221*	0.257**	0.985**	0.026	0.265**
	G			1.000	-0.138	0.537	-0.260	0.233	0.266	1.019	0.027	0.273
Seedling length at 40°C	P				1.000	-0.029	0.548**	-0.256**	-0.273**	-0.101	0.906**	-0.234*
	G				1.000	-0.036	0.556	-0.256	-0.277	-0.103	0.918	-0.257
Seedling fresh weight at 30°C	P					1.000	-0.133	0.584**	0.277**	0.493**	-0.020	0.464**
	G					1.000	-0.136	0.602	0.281	0.499	-0.021	0.490
Seedling fresh weight at 40°C	P						1.000	-0.055	-0.517**	-0.218*	0.425**	-0.232*
	G						1.000	-0.053	-0.518	-0.218	0.429	-0.247
Seedling dry weight at 30°C	P							1.000	0.094	0.221*	-0.265**	0.489**
	G							1.000	0.095	0.223	-0.273	0.521
Seedling dry weight at 40°C	P								1.000	0.222*	-0.215*	0.420**
	G								1.000	0.223	-0.218	0.444
Seedling vigor index at 30°C	P									1.000	0.059	0.245*
	G									1.000	0.058	0.256
Seedling vigor index at 40°C	P										1.000	-0.263**
	G										1.000	-0.278
Seed yield per plant	P											1.000
	G											1.000

Table 5: Estimates of phenotypic and genotypic path coefficient of mungbean genotypes on seed yield for seedling characteristics

Character		Germination per cent at 30 °C	Germination per cent at 40 °C	Seedling length at 30 °C	Seedling length at 40 °C	Seedling fresh weight at 30 °C	Seedling fresh weight at 40 °C	Seedling dry weight at 30 °C	Seedling dry weight at 40 °C	Seedling vigor index at 30 °C	Seedling vigor index at 40 °C	Correlation with seed yield per plant
Germination per cent at 30 °C	P	-0.4365	-0.1256	-0.1033	-0.026	-0.0351	-0.0204	-0.0522	-0.009	-0.1712	-0.0821	-0.009
	G	-0.0299	0.0281	0.0261	0.0043	0.0019	0.0045	0.0116	0.0017	0.0422	0.0198	-0.068
Germination percentage at 40 °C	P	0.0132	0.0459	0.0166	0.0044	0.0021	-0.0039	-0.0022	0.0049	0.0174	0.0222	-0.096
	G	0.0313	-0.0333	-0.0131	-0.0033	-0.0016	0.0031	0.0014	-0.0037	-0.0136	-0.0170	-0.102
Seedling length at 30 °C	P	-0.5093	-0.7800	-2.1518	0.2643	-1.1156	0.5440	-0.4748	-0.5525	-2.1184	-0.0569	0.265**
	G	0.0993	-0.0447	-0.1135	0.0156	-0.0609	0.0296	-0.0265	-0.0302	-0.1157	-0.0030	0.273
Seedling length at 40 °C	P	0.0182	0.0290	-0.0375	0.3052	-0.0089	0.1672	-0.0782	-0.0834	-0.0307	0.2765	-0.234*
	G	-0.0353	0.0245	-0.0338	0.2455	-0.0089	0.1365	-0.0629	-0.0680	-0.0252	0.2254	-0.257
Seedling fresh weight at 30 °C	P	0.0118	0.0067	0.0762	-0.0043	0.1470	-0.0196	0.0858	0.0407	0.0725	-0.0030	0.464**
	G	-0.0114	0.0091	0.0984	-0.0066	0.1833	-0.0250	0.1103	0.0515	0.0914	-0.0039	0.490
Seedling fresh weight at 40 °C	P	-0.0008	0.0015	0.0044	-0.0096	0.0023	-0.0176	0.0010	0.0091	0.0038	-0.0075	-0.232*
	G	0.0041	0.0026	0.0071	-0.0152	0.0037	-0.0273	0.0014	0.0141	0.0060	-0.0117	-0.247
Seedling dry weight at 30 °C	P	0.0432	-0.0174	0.0798	-0.0927	0.2113	-0.0198	0.3618	0.0338	0.0798	-0.0960	0.489**
	G	-0.1292	-0.0143	0.0774	-0.0852	0.1999	-0.0177	0.3322	0.0315	0.0740	-0.0908	0.521
Seedling dry	P	0.0078	0.0407	0.0972	-0.1034	0.1048	-0.1958	0.0354	0.3785	0.0842	-0.0815	0.420**

weight at 40 °C	G	-0.0199	0.0384	0.0918	-0.0954	0.0968	-0.1785	0.0327	0.3445	0.0769	-0.0749	0.444
Seedling vigor index at 30 °C	P	0.9132	0.8832	2.2930	-0.2344	1.1483	-0.5075	0.5137	0.5180	2.3291	0.1375	0.245*
	G	-0.1957	0.0565	0.1412	-0.0142	0.0691	-0.0302	0.0309	0.0309	0.1385	0.0081	0.256
Seedling vigor index at 40 °C	P	-0.0701	-0.1799	-0.0098	-0.3375	0.0075	-0.1583	0.0989	0.0803	-0.0220	-0.3726	-0.263**
	G	0.2187	-0.1683	-0.0087	-0.3029	0.0070	-0.1415	0.0902	0.0718	-0.0192	-0.3300	-0.278

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