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Estimation of genetic variability and interrelationship among yield and yield related charactres in mung bean (*Vigna radiata* (L.) Wilczek)

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Abstract
Forty mung bean (*Vigna radiata* (L.) Wilczek) genotypes were evaluated for the estimation of genetic variability parameters, correlation coefficient, path analysis, heritability and genetic advance. The genotypes differed significantly for all the characters. Higher GCV and PCV was observed for the number of primary branches per plant and number of pods per plant. High heritability coupled with genetic advance as percent of mean showed by number of primary branches per plant indicating the impact of additive gene expression. The characters days to 50 % flowering, number of pods per cluster, number of seeds per pod and harvest index showed positive and significant correlation along with positive direct effect on grain yield. Therefore, selection based on this component traits would results improvement in grain yield of mung bean.

Keywords: Mung bean (*Vigna radiata* (L.) Wilczek), genetic variability, heritability, genetic advance, correlation analysis, path coefficient analysis

Introduction
Mung bean [*Vigna radiata* (L.) Wilczek] also known as greengram is one of the most important pulse crops of Asia. It is a short duration legume crop belongs to the order Leguminosae and Papilionoideae family. It is a self-pollinating diploid legume with the chromosome number 2n=2x=22 (Karpechenko, 1925) [11]. Mung (Greengram) was sown over an area of 4.26 Mha in (kharif + rabi) and recorded a production of 2.01 Mt at and yield level of 472 kg/ha. During 2017-2018 the total coverage under mung bean. In Uttar Pradesh 0.72 Lha with a production 0.40 Lt. and the productivity 555.56 (kg/ha). It can be grown in various crop rotation practices (Singh *et al.*, 2015) [21] because of its short duration nature, wider adaptability, low water requirement and photo insensitiveness. Mung bean is short day, warm season crop, grown mainly in arid and semi-arid regions. It is drought tolerant and has ability to grow under harsh climate and medium to low rainfall situation. It is grown on a variety of soils including black, red lateritic, gravelly and sandy soils. Well drained fertile sandy loam soil with a pH between 6.2- 7.2 is best for mung bean cultivation. Water logged and saline soils are not suitable for mung bean cultivation (Sharma, 2016).

Correlation coefficient analysis is a statistical technique which measures the degree and association between two or more variables. Estimates of correlation coefficient are useful in identifying the component traits which can be used for yield improvement of mung bean. Path coefficient analysis provides a thorough understanding of contribution of various characters by partitioning the correlation coefficient into components of direct and indirect effects (Wright, 1921) [25], which helps the breeder in determining the yield components. To accumulate optimum contribution of yield contributing characters, it is essential to know the association of various characters along with path coefficients (Bhutia *et al.* 2016) [2]. Therefore, present study was conducted to assess correlation and path analysis to identify component traits for developing high yielding varieties of mung bean.

Material and Methods
The present investigation was carried out at the Field Experimentation Centre, Department of Genetics and Plant Breeding, SHUATS, Prayagraj (U.P.) during *Zaid*, 2019.

The University is situated on the left side of Prayagraj - Rewa National Highway, about 5 km away from Prayagraj city. All types of facilities necessary for cultivation of successful crop including field preparation, inputs and irrigation facilities were provided from the Department of Genetics and Plant Breeding, SHUATS, Prayagraj (U.P.). The experiment was conducted in randomized block design with 40 genotypes the genotypes were replicated 3 times. Genotypes were randomly arranged in each replication divided into 120 plots. The gross area of experiment was 263 m^2 and cash plot size was 1 x 1 m. The row to row spacing was 30 cm and plant to plant distance was 10 cm. The 5 competitive plants from each of the replication were tagged and observations were taken from these tagged plants at various stages of the crop plant growth. Data were recorded from 13 characters *viz*, days to 50 % flowering, days to maturity, plant height (cm), number of primary branches per plant, number of cluster per plant, number of pods per cluster, number of pods per plant, pod length (cm), number of seeds per pod, 100 seed weight (g), biological yield(g), harvest index and grain yield per plant(g). mean values were computed data were analysed for analysis of variance as suggested by (Fisher, 1936) [6] and coefficient of variances as well as heritability (in broad sense), as suggested by Burton and Devane (1953). The estimates of genetic advance were obtained by the formula suggested by Lush (1949) [15] and 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) [5].

Results and Discussion

The genotypic and phenotypic coefficient of variation, heritability and genetic advance as percent of mean for each of the characters are presented in Table-1. Considerable range in variation was observed for all characters. Phenotypic coefficients of variation values were relatively higher than corresponding genotypic coefficient of variation for all traits under study. Phenotypic Coefficient of variation (PCV) ranged from days to maturity (4.20) to number of primary branches per plant (24.825). High PCV magnitude was recorded for number of primary branches per plant (24.82) and number of pods per plant (22.70). Moderate values of plant height were also observed by Khan *et al.* (2008) [12]. Genotypic coefficient of variation which gives the extent of genetic variability in the population, ranged from 1.72 to 20.10 per cent. Maximum genotypic coefficient of variation was observed for number of primary branches per plant (20.10). While moderate GCV was recorded for number of pods per plant (10.57). High phenotypic coefficient of variation and genotypic coefficient of variation were observed for number of primary branches per plant and number of pods per plant. Similar findings were reported by Makeen *et al*. (2007) [16] and Saxesena *et al*. (2014) [1]. Indicating the influence of environmental factors less difference were observed between phenotypic and genotypic coefficient of variation in certain cases such as numbers of primary branches per plant, days to 50% flowering, 100 seed weight, number of seeds per pod, biological yield and days to maturity. Which indicated that these characters were less influenced by the environmental. Similar results also obtained by Singh *et al.* (2009) [23] and Kumar *et al.* (2013) [13]. The estimates of heritability (%) in the broad sense for 13 characters studied, which range from 16.42 to 68.23. High heritability (broad sense) was recorded for characters like pod length (68.23) and number of primary branches per plant (65.60). The higher heritability value was registered by the characters under study *viz*, plant height and number of primary branches per plant. Similar finding were obtained Reddy *et al.* (2003) [20], Srivastava and singh (2012) [22]. Genetic advance as % of mean varied from 1.42 to 33.53. High genetic advance as % mean was recorded for number of primary branches per plant (33.53). The estimated were high for number of primary branches per plant was reported by Singh *et al.* (2009) [23] and Reddy *et al.* (2011) [19]. Correlation coefficient analysis among grain yield and its contributing characters are shown in Table 2. There was positive, significant and strong correlation of this trait with days to 50 % flowering, number of pods per cluster, number of pods per plant, number of seeds per pod and harvest index at both genotypic and phenotypic levels. Similar results were reported by Venkateswarlu (2001) [24], Haritha and Reddy (2002) [8], Nazir *et al*. (2005) [18], Tejbir Singh *et al*. (2009) [23] and Reddy *et al*. (2011) [19] for seed yield with number of pods per plant, number of pods per cluster, number of clusters per plant, number of seeds per pod. Ahmad *et al.* (2013) [1] also observed positive genotypic association of seed yield with number of cluster per plant, number of pods per plant. Kumar *et al*. (2013) [13] and Narasimhulu *et al*. (2013) [17] also found with number of seeds per pod. Khan *et al*. (2001), Saxena *et al*. (2007) and Ahmad *et al*. (2013) [1] Bhutia *et al.* (2016) [2] and Choudhary *et al*. (2016) similar results found for harvest index at phenotypic level. Path coefficient analysis was carried out by taking grain yield as dependent variable to partition the correlation coefficient into direct and indirect effects in order to determine the contribution of different characters towards the grain yield. Direct and positive effect on grain yield per plant was observed for characters like days to 50 % flowering, number of primary branches per plant, number of pods per plant, pod length, plant height, number of seeds per pod, 100 seed weight, biological yield and harvest index. Similar results were reported by Gadakh *et al.* (2013) [7], Kapadia *et al.* (2015) [10], Bhutia *et al.* (2016) [2] and Choudhary *et al.* (2016). Days to maturity and number of primary branches per plant had negative direct effect on seed yield per plant. Similar findings were reported by Kumar *et al.* (2004) [14] and Choudhary *et al.* (2016) in mung bean. Hence, presently study reveals that number of pods per plant, biological yield, harvest index, number of seeds per pod, 100 seed weight and pod length are important agronomic traits as they have directly contributed towards grain yield, plant height and days to 50 per cent flowering also had direct effect on seed yield. Therefore, more emphasis should be given to these components during selection for higher yield. The interrelationship among yield components would help in increasing the yield levels.

Table 1: Genetic parameters for 13 characters in mung bean

Sr. No	Character	VG	VP	GCV	PCV	h^2bs	GA	GA as % mean
1	Days to 50% flowering	1.61	3.09	3.49	4.84	52.10	1.88	5.17
2	Days to maturity	1.09	6.67	1.70	4.20	16.42	0.87	1.42
3	Plant height	7.15	37.50	4.94	11.31	19.07	2.41	4.44
4	Primary branches/ plant	0.30	0.45	20.10	24.82	65.60	0.91	33.537

5	No. of clusters/ plant	0.09	0.24	7.91	13.20	35.94	0.36	9.77
6	No. of pods/ cluster	0.05	0.11	8.29	12.84	45.45	0.28	11.02
7	No. of pods/ plant	1.81	8.36	10.57	22.70	21.67	1.29	10.13
8	Pod length	0.14	0.20	5.44	6.59	70.00	0.63	9.26
9	No. of seeds/ pod	0.15	0.39	4.20	6.72	38.99	0.50	5.40
10	100 seed weight	0.20	0.36	9.99	13.48	54.93	0.68	15.25
11	Biological yield	0.31	1.45	2.69	5.84	21.22	0.53	2.55
12	Harvest index	3.27	9.68	5.71	9.83	33.72	2.16	6.85
13	Grain yield/ plant	0.05	0.18	3.19	6.92	27.77	0.20	3.02

VG= Genotypic variance VP = Phenotypic variance
GCV=Genotypic coefficient of variation PCV= Phenotypic coefficient of variation
h^2 (bs) = Heritability broad sense GA= Genetic advance

Table 2: Correlation coefficient between yield and its related traits in mung bean genotypes at genotypic level

Sr. No	Character	Days to 50 % flowering	Days to maturity	Plant height	Primary branches / Plant	No.of. clusters / plant	No.of. Pods / cluster	No.of. pods / Plant	Pod length	No.of. seeds / pod	100 Seed weight	Biological yield	Harvest index	Grain yield / plant
1	Days to 50% flowering	1	-0.022	-0.339**	0.516**	0.249**	0.475**	-0.121	-0.112	0.382**	-0.332**	-0.022	0.248**	0.326**
2	Days to maturity		1	0.553**	-0.440**	-0.391**	-0.107	-0.900**	-0.511**	-0.517**	-0.405**	0.332**	-0.412**	0.172
3	Plant height			1	0.329**	-0.321**	-0.608**	-0.621**	0.510**	0.198*	0.027	0.449**	-0.494**	-0.498**
4	Primary branches/ plant				1	0.256**	0.369**	0.640**	0.024	0.307**	-0.04	-0.526**	0.308**	0.035
5	No.of.clusters / plant					1	-0.036	0.717**	0.333**	0.057	-0.255**	-0.463**	0.313**	0.129
6	No.of.pods / cluster						1	-0.054	-0.09	-0.219*	0.103	-0.142	-0.024	0.336**
7	No.of. pods / plant							1	0.492**	0.406**	-0.238**	-0.784**	0.510**	0.299**
8	Pod length								1	0.283**	0.262**	-0.225*	-0.056	-0.304**
9	No. of. seeds /pod									1	-0.106	-0.264**	0.231*	0.426**
10	100 seed weight										1	-0.414**	0.186*	0.052
11	Biological yield											1	-0.612**	0.015
12	Harvest index												1	0.802**

Table 3: Correlation coefficient between yield and its related traits in Mung bean genotypes at phenotypic level

Sr. No	Characters	Days to 50 % flowering	Days to maturity	Plant height	Primary branches/ plant	No. of clusters/ plant	No. of pods/cluster	No. of pods/plant	Pod length	No. of seeds/pod	100 seed weight	Biological yield	Harvest index	Grain yield/ plant
1	Days to 50% flowering	1	0.058	-0.172	0.292**	0.115	0.312**	0.018	-0.033	0.192*	-0.121	-0.074	0.119	0.225*
2	Days to maturity		1	-0.287**	-0.028	-0.243**	-0.059	-0.428**	-0.09	-0.082	-0.08	0.179	-0.206*	-0.112
3	Plant height			1	0.013	0.117	-0.043	0.291**	0.131	0.064	-0.288**	0.019	0.002	0.04
4	Primary branches/ plant				1	0.175	0.218*	0.125	0.014	0.194*	-0.213*	-0.174	0.096	-0.189*
5	No. of clusters/ plant					1	0.081	0.435**	0.1	-0.387**	-0.039	-0.179	0.136	0.452**
6	No. of pods/ cluster						1	0.003	-0.217*	-0.049	-0.328**	-0.057	0.011	0.398**
7	No. of Pods/plant							1	0.166	0.161	-0.023	-0.182*	0.168	0.122
8	Pod length								1	0.075	0.212*	-0.063	-0.063	-0.13
9	No. of Seeds/ pod									1	-0.101	-0.219*	0.155	0.433**
10	100 seed weight										1	0.017	-0.032	-0.316**
11	Biological yield											1	-0.646**	-0.107
12	Harvest index												1	0.768**

Table 4: Direct and indirect effects between yield and its different traits in Mung bean genotypes at genotypic level

Sr. No	Characters	Days to 50% Flowering	Days to Maturity	Plant Height (cm)	Primary Branches per Plant	Clusters per plant	Pods per Cluster	Pods per Plant	Pod Length in	Seeds per pod	100 Seed Weight	Biological yield	Harvest Index	Grain Yield per plant
1	Days to 50% Flowering	0.7531	0.0075	0.2242	0.0205	-0.3279	-0.7744	-0.0579	-0.0262	-0.5091	0.7644	-0.0548	0.17871	0.326
2	Days to maturity	-0.0381	-0.3426	-0.3660	-0.0175	0.5156	0.1739	-0.4302	-0.1196	0.6890	0.6027	0.8306	-0.61857	0.172
3	Plant Height	-0.5936	-0.1894	-0.6622	0.0130	0.4228	0.9908	-0.2968	0.1194	-0.2643	-0.3088	0.1256	-0.33664	-0.498
4	Primary Branches per Plant	0.9053	0.1509	-0.2178	0.0396	-0.3372	-0.6014	0.3059	0.0056	-0.4093	0.4593	-0.3173	0.70795	0.035

5	Clusters per Plant	0.4363	0.1341	0.2125	0.0101	-0.3173	0.0593	0.3427	0.0779	-0.0766	0.8915	-0.1609	0.74845	0.129
6	Pods Per Cluster	0.8332	0.0366	0.4026	0.0146	0.0480	-0.6294	-0.0258	-0.0211	0.2924	-0.1646	-0.3554	-0.21244	0.336
7	Pods per Plant	-0.2123	0.3083	0.4111	0.0254	-0.9441	0.0878	0.4781	0.1151	-0.5407	0.7069	-0.9632	0.48254	0.299
8	Pod Length	-0.1961	0.1750	-0.3374	0.0009	-0.4381	0.1465	0.2350	0.2342	-0.3766	-0.9771	-0.5638	-0.49062	-0.304
9	Seeds per pod	0.6699	0.1772	-0.1314	0.0122	-0.0757	0.3576	0.1940	0.0662	-0.3323	0.1993	-0.6608	0.02831	0.426
10	100 Seed Weight	-0.5812	0.1389	-0.0180	-0.0016	0.3354	-0.1671	-0.1140	0.0614	0.1407	-0.3553	-0.0359	0.63145	0.052
11	Biological Yield	-0.0383	-0.1136	-0.2975	-0.0208	0.6104	0.2311	-0.3747	-0.0527	0.3514	0.6955	0.5053	-0.38052	0.015
12	Harvest Index	-0.7434	-0.5945	-0.0761	-0.6106	0.9116	-0.3664	-0.9722	0.3180	0.7569	-0.1736	-0.4331	0.7856	0.802

Table 5: Direct and indirect effects between yield and its different traits in Mung bean genotypes at phenotypic level

Sr. No	Character	Days to 50% Flowering	Days to Maturity	Plant height	Primary Branches per Plant	Clusters per plant	Pods Per cluster	Pods per Plant	Pod Length	Seeds per pod	100 Seed Weight	Biological yield	Harvest Index	Grain Yield per plant
1	Days to 50% Flowering	0.1685	-0.0064	-0.0113	-0.0390	-0.0062	-0.0060	-0.0002	0.0043	0.0012	-0.1559	0.0482	-0.0472	0.225
2	Days to maturity	0.0098	-0.1109	-0.0189	0.0037	0.0130	0.0018	0.0059	0.0116	-0.0006	-0.1034	-0.1165	0.1142	-0.112
3	Plant Height	-0.0291	0.0318	0.0657	-0.0018	-0.0063	0.0013	-0.0040	-0.0169	0.0004	-0.0380	-0.0127	0.0124	0.040
4	Primary Branches per Plant	0.0492	0.0031	0.0009	-0.1333	-0.0094	-0.0065	-0.0017	-0.0018	0.0013	-0.0164	0.1129	-0.1107	-0.189
5	Clusters per Plant	0.0195	0.0269	0.0077	-0.0234	-0.0534	-0.0024	-0.0060	-0.0129	0.0007	-0.0496	0.1165	-0.1142	0.452
6	Pods Per Cluster	0.0340	0.0065	-0.0028	-0.0291	-0.0043	-0.0297	0.0000	0.0022	-0.0003	-0.0362	0.0369	-0.0362	0.398
7	Pods per Plant	0.0030	0.0475	0.0191	-0.0166	-0.0232	-0.0001	-0.0138	-0.0214	0.0011	-0.0294	0.1183	-0.1160	0.122
8	Pod Length	-0.0056	0.0100	0.0086	-0.0019	-0.0053	0.0005	-0.0023	-0.1287	0.0005	0.2732	0.0411	-0.0403	-0.130
9	Seeds per pod	0.0298	0.0091	0.0042	-0.0259	-0.0054	0.0015	-0.0022	-0.0096	0.0069	-0.1306	0.1425	-0.1397	0.433
10	100 Seed Weight	-0.0204	0.0089	-0.0019	0.0017	0.0021	0.0008	0.0003	-0.0273	-0.0007	0.2874	-0.0108	0.0106	-0.316
11	Biological Yield	-0.0125	-0.0199	0.0013	0.0231	0.0096	0.0017	0.0025	0.0081	-0.0015	0.0213	-0.6507	0.6378	-0.107
12	Harvest Index	0.0059	-0.0006	0.0001	-0.0087	-0.0061	0.0002	-0.0081	0.0007	0.0014	-0.0007	-0.4121	0.1955	0.768

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